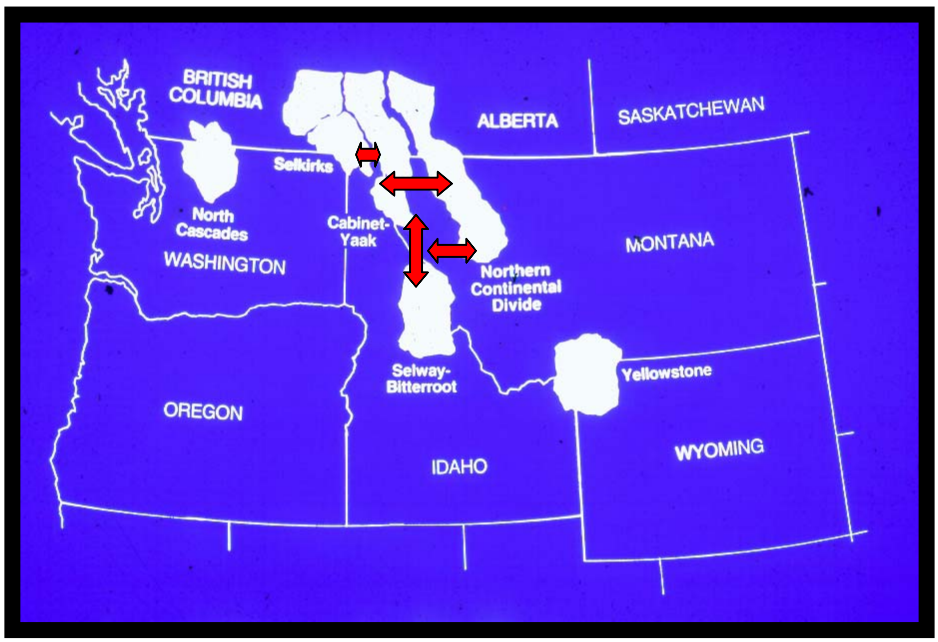
Updated July 8, 2003

Identification and Management of Linkage Zones for Wildlife Between the Large Blocks of Public Land in the Northern Rocky Mountains



Christopher Servheen
John S. Waller
Per Sandstrom

U.S. Fish and Wildlife Service
College of Forestry and Conservation
University Hall 309
University of Montana
Missoula, Montana 59812
Updated 7/8/03

EXPECTED RESULTS FROM THIS REPORT

The expected results of this report will be the development of an organized effort to implement linkage zone management to maintain and enhance opportunities for movement of wildlife between the existing large blocks of land in the Rocky Mountains.

This cooperative effort will involve:

- **Public land management agencies**
- **Private landowners**
- **Corporate landowners**
- **State fish and game agencies**
- **State land departments**
- **State and Federal highway departments**
- **County commissioners**
- **Land conservation organizations**

This joint effort will seek to:

- **Assure that private land owners have the opportunity to participate and to shape this effort to make it compatible with their needs and concerns**
- **Assure that public lands will be managed in a way to allow wildlife to use linkage zones and the approach lands that lead to linkage zones**
- **Assure that highway development and improvement in linkage zones will facilitate highway crossing by wildlife and minimize mortality risk to animals trying to cross highways**

This is an updated version of the original Linkage Zone Report that was released 7/17/01 and last updated 9/4/01. This update makes the document more generic. No linkage zones have been changed from the original report.

Executive Summary

Habitat fragmentation occurs when contiguous blocks of habitat are broken into pieces, with the pieces being separated from one another by unsuitable habitats. Habitat fragmentation is usually accompanied by habitat loss. Populations that are dramatically reduced in size and isolated from one another on small habitat "islands" are at increased risk of extinction. Extinction risk increases because small populations are less able to absorb losses caused by random environmental, genetic, and demographic changes. The primary causes of wildlife habitat fragmentation are human activities such as road building, and residential, recreational, and commercial developments. When developments reach a certain concentration, they become impermeable and are termed "habitat fracture zones". Maintaining connectivity or "linkage" between wildlife populations across the landscape will make for healthier populations and could prevent many of the detrimental consequences of habitat fragmentation. Maintaining opportunities for wildlife movement across the landscape maintains the natural processes that animals have used for centuries. This document describes the methods and results of an evaluation to identify where wildlife movement is still possible between the large blocks of land in the Northern Rockies and a cooperative process to assure that those wildlife movement opportunities remain available in the future.

For this report, we evaluated the extent of habitat fracture and potential for wildlife linkage between the Cabinet/Yaak and Bitterroot areas; Cabinet/Yaak and Selkirk areas; NCDE and Bitterroot areas; and between the NCDE and Cabinet/Yaak areas[1]. We also examined the potential for linkage between the Cabinet Mountains and Yaak River drainage within the Cabinet/Yaak area.

We used a computerized geographic information system (GIS) to model and graphically display the opportunities for wildlife movement between areas. Our linkage zone prediction model (LZP) was developed to quantify, in repeatable fashion, the extent to which human development has limited potential for movement between the large blocks of public land in the Northern Rockies. The model scores the landscape as to its permeability for wildlife movement based on 4 data layers: road density, developed sites, visual cover, and riparian zones as the base vegetation layer. Each of the 4 input data layers were combined into one new layer displaying the combined impact of each of these factors on habitat quality. Combined scores were then divided into 4 categories based upon subjective evaluation. Maps of combined impact scores were then used to identify linkage zones.

Each linkage zone evaluation area had different amounts of habitat fragmentation, thus precluding movement between large blocks of public land to varying degrees. Most development occurred on private lands in valley bottoms. In the Cabinet/Yaak to Bitterroot evaluation area, potential fracture of habitat was severe between Plains, Montana and the Idaho border along Montana Highway 200. There was some opportunity for movement across I-90 between Superior, Montana and Lookout Pass. The Cabinet/Yaak to Selkirks evaluation was nearly completely severed by developments along US-95. The only possible linkage area between the NCDE and the Bitterroots is the Evaro Hill area. US-12 represents a minimal obstacle due to

---

[1] This report does not report on the analysis between Yellowstone and ecosystems to the north. That analysis will be reported separately when it is complete.

limited development from approximately 10 miles west of Lolo, Montana to Lolo Pass. Linkage opportunities between the NCDE and the Cabinet/Yaak are still possible but development continues along US-93 between Whitefish and Eureka, Montana. Potential linkage areas remain between Olney and Trego, Montana along Highway 93. Potential linkage areas across US Highway 2 remain between Marion and Libby, Montana. Development along US Highway 2 between Troy and Libby, Montana fragments a portion of the Cabinet/Yaak area. Steep terrain along portions of this highway segment has precluded development, but may still allow linkage in the small-undeveloped portions.

The linkage zone across Highway 93 in the Evaro Hill area of Montana is not covered in this report. Steve Mietz completed this analysis as a Master of Science thesis at the University of Montana. This thesis covers this linkage zone area in detail and should be referenced for information on linkage in this area.

This assessment of potential linkage areas presents a challenging picture for connectivity between the large blocks of public land in the Northern Rockies. Active management will be necessary to maintain what opportunities for linkage exist and to enhance opportunities where linkage is minimal at this time. Considerations for model interpretation and options for conservation and management are discussed.

Acknowledgements
We would like to acknowledge the expertise and efforts of Steve Meitz in making the linkage zone concept a reality. Thanks also to Wayne Kasworm for critical review and comment and to Lauren Caldwell and Carolyn Toepke for careful proof reading. Special thanks to Jim Schumacher and Roly Redmond and the staff of the Wildlife Spatial Analysis Lab at the University of Montana who provided technical assistance and GIS facilities.

Table of Contents

List of Tables

List of Figures

List of Figures (continued)

Introduction

The Issue of Scale for Linkage Zones and Crossing Sites

The identification of linkage zones is a way to stratify areas where opportunities for movement still exist between large blocks of habitat. Each linkage zone is from one to several miles or more in width. The Linkage Zone Prediction (LZP) model is not designed to predict the most likely specific locations within each linkage zone that may be used by wildlife to get across each zone. Various scales exist at the landscape level to view the distribution and linkage of wildlife populations. These scales vary from the general distribution of species to site-specific locations where movement routes or sites occur across highways and through linkage zones (Figure 1). Our current level of knowledge does not yet allow us to predict specific crossing routes or sites, or to predict what combinations of topographic features, vegetation characteristics, road structures, or other values that may be most likely to be used by wildlife to select areas to get across linkage zones. Work is now progressing on ways to attempt to predict such crossing sites (Servheen et al. 1998). If it were possible to predict

What is a linkage zone?

- The area between larger blocks of habitat where animals can live at certain seasons and where they can find the security they need to successfully move between these larger habitat blocks
- Linkage zones are broad areas of seasonal habitat where animals can find food, shelter, and security

The need for linkage consideration:

- The long-term health of wildlife populations will benefit from linkage wherever possible
- Linkage areas can likely serve multiple wildlife species
- Dramatic changes are occurring in the remaining possible linkage areas due to ongoing human development
- Time to maintain connection opportunities is growing short due to the pace of development on these lands

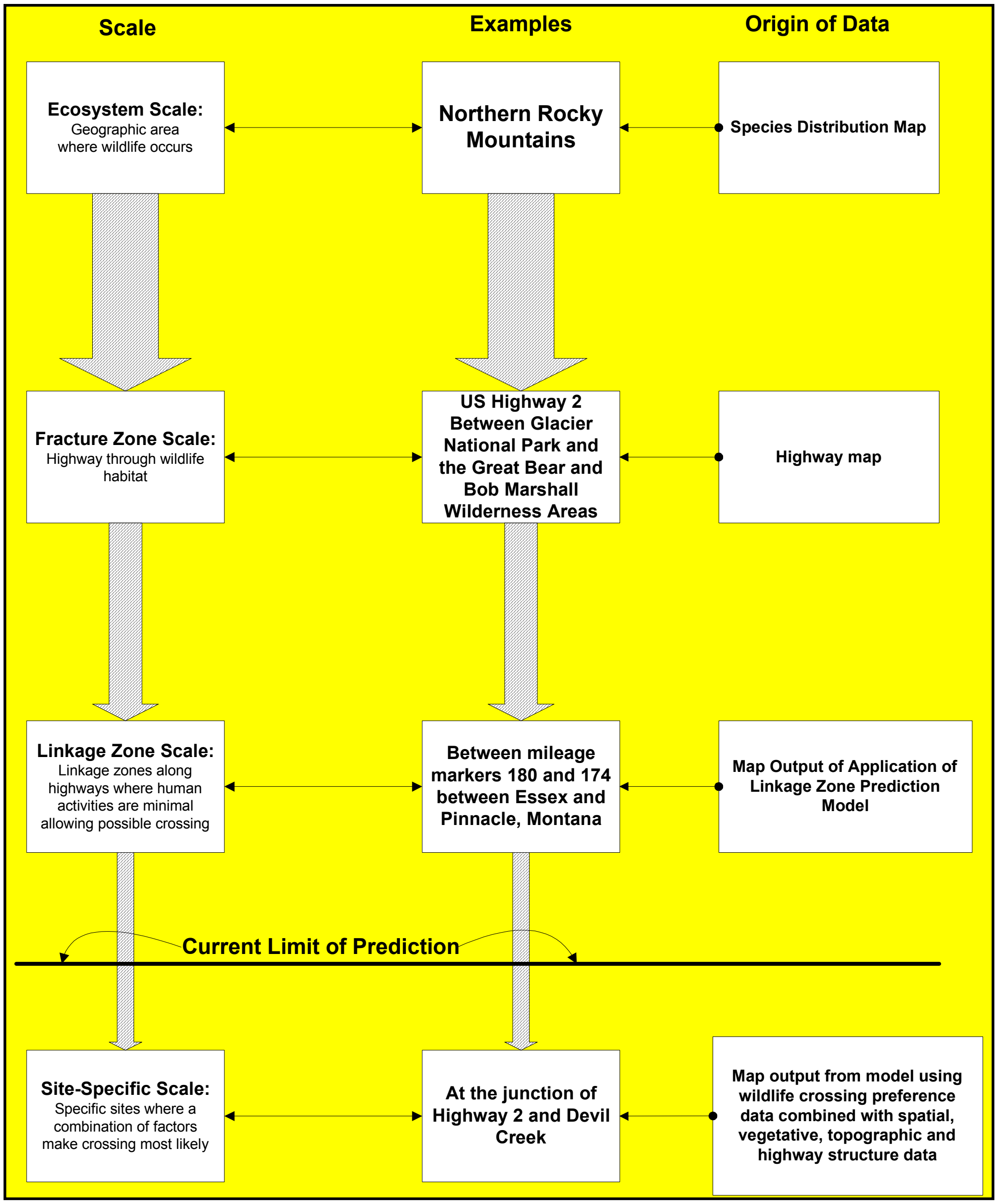


Figure 1. Scales of resolution for linkage zone consideration. Currently, the finest level of resolution is at the linkage zone level. Future work involving site-specific documentation of wildlife crossing sites using GPS collars and multivariate analysis may allow future identification at the site-specific scale of crossings (from Servheen et al. 1998).

characteristics for crossing sites for wildlife, these would be of great value to highway engineers for placement of crossing structures in the most important locations. This report does not identify these specific crossing sites within each linkage zone. Such identification is a future effort that should be attempted in each linkage zone based on further efforts.

Why is a linkage zone not a "corridor"?

- A "corridor" implies an area just used for travel, however movement between ecosystems by animals rarely occurs this way
- For wildlife to get between ecosystems they require habitats that can support their feeding and behavioral needs in these intervening areas
- Linkage zones are areas that will support low density wildlife populations often as seasonal residents - <u>they are not just travel areas</u>

Where are the Analysis Areas?

For this report, we evaluated the extent of habitat fracture and potential for linkage between the Cabinet/Yaak and Bitterroot areas; Cabinet/Yaak and Selkirk areas; NCDE and Bitterroot areas; and between the NCDE and Cabinet/Yaak areas (Figure 2). We also examined the potential for linkage between the Cabinet Mountains and the Yaak River drainage within the Cabinet/Yaak area. An evaluation of habitat fractures and potential linkage between the Yellowstone area and the NCDE and Bitterroot areas will be addressed in a later document.

The North Cascades and Linkage

This report does not contain an analysis of linkage possibilities between the North Cascades and the Selkirks. This is due to limits on funding available for such an analysis at this time. Linkage between the North Cascades and the Selkirks will be accomplished and reported when funding is available for this effort. There is a need to consider this possible linkage on both the US and Canadian sides of the border between these two ecosystems. A recent report (Singleton et al. 2002) analyzes the area to the east and south of the North Cascades for wildlife linkage.

Cabinet/Yaak to Bitterroot - This linkage evaluation area encompassed 3,606 square miles and contained 5 primary transportation corridors: Interstate 90 and Montana state highways 28, 56, 135, and 200.

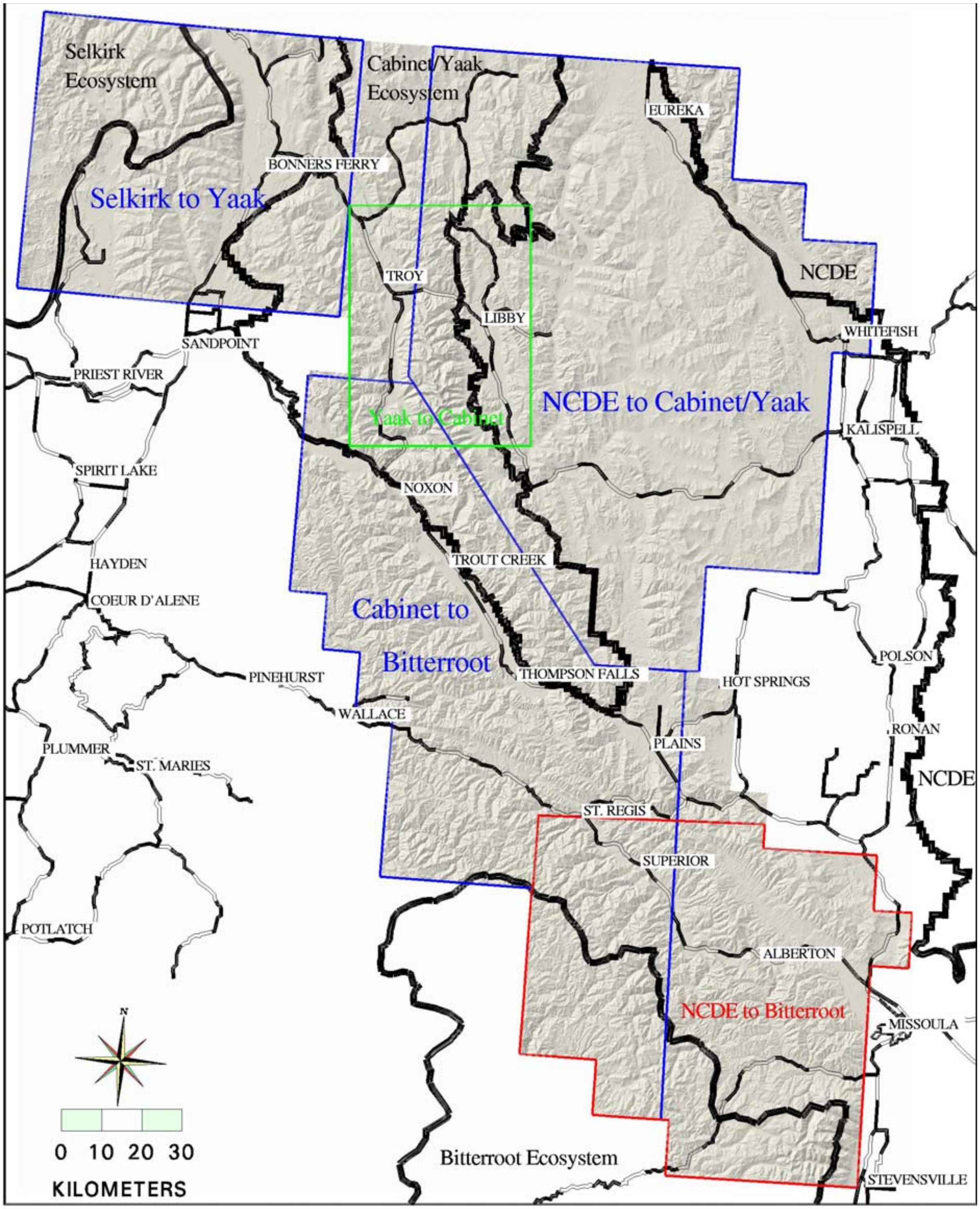


Figure 2. Five Linkage Zone Prediction Model evaluation areas with terrain, cites, recovery area boundaries, and major highways shown.

Two of these highways, Interstate 90 and Montana 200, formed potential barriers to wildlife movement between the Cabinet/Yaak and Bitterroot areas. Approximately 88% of the area was public land, primarily within the Kootenai, Clearwater, Idaho Panhandle, and Lolo National Forests. The area was mountainous with elevations ranging from 2047 ft. in the Clark Fork River valley to 7928 ft. in the higher peaks of the Bitterroot Range. Most private land and development occurred in the valleys formed by the Clark Fork and St. Regis rivers and paralleling the 5 primary highways. Timber harvest was the primary use of surrounding National Forest lands, thus forest road densities were relatively high.

Cabinet/Yaak to Selkirks - This linkage evaluation area encompassed 2,124 square miles and contained 4 primary transportation corridors: U.S. highways 2 and 95, and Idaho state highways 1 and 57. Approximately 75% of the evaluation area was public land, primarily within the Idaho Panhandle and Kootenai National Forests, and Idaho's Priest Lake State Forest. However, significant amounts of private land, and most developments, occurred in the Purcell Trench and the communities of Sandpoint and Bonners Ferry, Idaho. Timber harvest was the primary use of surrounding public lands, thus forest road densities were relatively high. Topography was mountainous with elevations ranging from 1709 ft. in the valley bottoms to 7688 ft. in the higher peaks of the Cabinet Mountains.

NCDE to Bitterroots - This linkage evaluation area encompassed 2,616 square miles and contained 3 primary transportation corridors: Interstate highway 90 and U.S. highways 12 and 93. Approximately 82% of the linkage area was public land, primarily within the Lolo and Clearwater National Forests. The area was very mountainous with elevations from 2630 ft. in the Clark Fork River valley to 9578 ft in the higher peaks of the Bitterroot Range. Most development occurred along the Clark Fork River and associated highways and roads between the city of Missoula and the Idaho border.

NCDE to Cabinet Yaak – This linkage evaluation area encompassed 4,919 square miles and contained 2 primary transportation corridors: U.S. highways 2 and 93. Public lands comprised 86% of the evaluation area, primarily within the Kootenai and Flathead National Forests and Montana's Stillwater State Forest. Within the linkage evaluation area, U.S. highway 93 connected the communities of Whitefish and Eureka, Montana and U.S. highway 2 connected Kalispell to Libby, Montana. Lake Koocanusa on the Kootenai River bisected the northwestern third of the linkage area from the northeastern two thirds. Terrain was moderately mountainous with elevations ranging from 1883 ft. in the Salish Range to 8738 ft. in the higher peaks of the Whitefish range.

Yaak River drainage to the Cabinets – The Yaak to Cabinets linkage area lies within the larger Cabinet/Yaak area. U.S. Highway 2 separates the Yaak River drainage from the Cabinet Mountains Wilderness, between the communities of Libby and Troy, Montana. It was important to evaluate movement within this area. It represents a situation where an existing fracture zone containing human developments could be continuing to fragment existing habitat. The Cabinet Mountains are quite mountainous with elevations ranging up to 8738 ft. The Yaak River drainage is less mountainous with elevations ranging down to 1801 ft. The linkage evaluation area encompassed 1,048 square miles, 92% in public ownership. Most of the private lands were in the Kootenai River valley along US Highway 2 and surrounding Troy, Bull Lake (south of Troy on Highway 56), and Libby.

Methods

Linkage zone prediction

- Depends on a GIS model to predict the broad areas of highest potential for linkage between habitat units for various animal species
- The main assumption is that human activities determine wildlife distribution in disturbed areas
- **This model uses 4 digital layers:**
  - Road density (using a moving window approach)
  - Human developed sites (i.e. houses, campgrounds, etc.) and the influence zone around them
  - Presence of or lack of vegetative hiding cover
  - Presence of riparian zones

Additionally, in some areas, livestock allotments may have an impact on linkage zones and may need special consideration.

We used a computerized geographic information system (GIS) to model and graphically display the opportunities for wildlife movement between areas. GIS allows numerous thematic layers to be combined into one graphic display. Each theme represents a feature of the environment, for example elevation, vegetation type, road networks, etc. Because these themes are combined using a computer algorithm, the process is repeatable over large landscapes

The linkage zone prediction model (LZP) was developed to quantify, in repeatable fashion, the extent to which human development has limited the potential for wildlife movement between areas. This model was developed by Mietz (1994) and Sandstrom (1996) and applied to the Evaro Hill and Swan Valley areas of Montana. A derivation of this model was used by Apps (1997) to define linkage areas in Southeastern British Columbia and Southwestern Alberta, Canada.

Because of their sensitivity to human activities, grizzly bears were a focus species when the linkage zone prediction model was developed. This was to attempt a more "conservative" model. It was assumed that if the model could reasonably meet the movement needs of grizzly bears, it would also represent the needs of many wildlife species. Previous evaluations of grizzly bear habitat focused on describing vegetation, particularly as potential food resources (Mace and Jonkel 1980, Craighead et al. 1982). More recent research has demonstrated that human activities can also have profound effects on distribution of grizzly bears (Mace et al. 1999). Our LZP model evaluated the potential for wildlife movement between areas by scoring the landscape based upon 4 data layers: roads, human-developed sites, vegetative cover conditions, and riparian habitat.

Roads - Human transportation corridors and their associated developments can cause fragmentation of the habitats of many different species (Garland and Bradley 1984). Recent research has demonstrated the negative effects of roads on grizzly bears (Archibald et al. 1987, Mattson et al. 1987, McLellan and Shackleton 1988, Kasworm and Manley 1990, Mace et al. 1996, Mace et al. 1999). Although wildlife such as bears are occasionally killed by motor vehicles on roadways, the primary impact is displacement from preferred habitats (Mace et al. 1999). Conversely, wildlife not displaced by roads are at higher risk of mortality from hunters, poachers, and management removal.

We compiled digital road data from the US Forest Service and the US Geological Survey for each linkage area. The road network was represented in digital form as “vectors”, and classified as either open to public travel or restricted in some manner. Two thematic layers were created from these data. The first depicted “total motorized access routes” (TMAR), and included all open roads, restricted roads, and motorized trails (IGBC 1994). Restricted roads included roads on which motorized use was restricted yearlong, or seasonally, by a physical obstruction (gate, berm, rocks, or logs). The second layer depicted all open roads, roads with motorized use restricted by a gate or a sign, and trails receiving high use (more than 12 parties per week, IGBC 1994). These “vector” files were converted to a “raster” format in which the landscape is portrayed as a grid of 30x30 meter cells. Each cell is coded as being a road (1) or not (0).

We calculated road density within each linkage zone evaluation area using the TMAR road layer in a “moving circle” analysis. A moving circle analysis assigns each pixel a road density in mi/mi^2 based on the number of road cells within a surrounding 1 mi diameter circle. The circle moves across the evaluation area, calculating road density, cell by cell. Road density values were then grouped into 4 categories: 0 mi/mi^2, 0.01 – 1.00 mi/mi^2, 1.01 – 2 mi/mi^2, and > 2 mi/mi^2. The categories were those used by Mace and Manley (1993) to measure and report effects of road density on grizzly bears.

The second road layer was used to create a map of secure core areas (SCA). All open roads, roads restricted by a gate or a sign, and trails receiving high use, received a 500 m buffer. All areas outside this buffer were considered SCA. Areas within a SCA are considered to be less impacted by human activity and where wildlife are at lower risk of displacement and mortality risk, thus are given a lower impact score (minimal), than areas outside SCA. The interactions between roads, SCA, developed sites, and vegetation were represented by an impact level ranking (Table 1).

Developed sites – Wildlife survival and habitat-use patterns are strongly influenced by the intensity of human activity around developed sites. Wildlife may respond negatively, neutrally, or positively. A negative response is avoidance of the area surrounding a developed site. A positive response is attraction to developed sites due to the presence of garbage or foods. Both negative and positive responses can be detrimental to wildlife.

Avoidance of developed sites may result in loss of important habitats while attraction may result in increased mortality. Developed sites usually become permanent features of the environment, and therefore need to be accommodated by land managers charged with wildlife management and conservation.

Input data for this layer consisted of digital maps of developed sites represented as point and polygon features. Polygon features represented campgrounds, livestock operations, communities, and other places that cover an area too large to be represented by a point. Data were obtained from USFS and USGS cartographic feature files. Each developed site represented a “human influence zone” which was then buffered by 60, 120, or 210 m depending on the type of activity occurring at the site. Various types of activities occurring at developed sites were subjectively categorized as to their “danger” to wildlife based on the judgment of biologists (Table 2).

There was no empirical basis for establishing these categories, so we employed a “best judgment” methodology (USFS 1994). In the LZP model, we coded all human influence zones as having a “high” or the strongest impact level. Human developments often represent permanent human presence and reduced land management opportunities. Thus, a developed site has a long term, permanent, negative impact on wildlife habitat quality for many species. We assumed that the influence of humans on wildlife declined as distance from a developed site increased. We incorporated this into the LZP model by creating two 120 m concentric zones around each human impact zone and classifying them as having moderate and low impact levels respectively. Distances greater than 240 m from the outer boundary of a human influence zone were considered neutral.

Cover conditions – Hiding cover is vegetation capable of shielding an animal from visual detection. Many definitions of hiding cover exist and tend to be specific to the species of interest. We used the Flathead National Forest definition of bear non-hiding cover (USFS 1992), which is “vegetation not capable of hiding 90% of an adult bear at 200 feet.” These open areas occurred naturally as a result of recent fires, as a consequence of environmental factors (climatic, edaphic) that discourage vegetation growth, and as a result of human activities, such as logging.

Many wildlife species seldom venture far from hiding cover during daylight hours in areas with frequent human activity (Blanchard 1978, Schallenberger and Jonkel 1980, Aune and Kasworm 1989), but seem unaffected by cover conditions where human presence is minimal (Servheen 1981). Open areas where humans are present are usually associated with roads or trails. Wildlife in direct view of roads and vehicles usually flee especially if the vehicles stop, whereas wildlife in protective cover are less affected by human presence (McLellan and Mace 1985, McLellan and Shackleton 1989, McLellan 1990).

Table 1. Estimated levels of impact on habitat quality from different categories of human activity and vegetation hiding cover conditions (Sandstrom 1996).

Category of condition	**Impact level**
Road Density (RD) 0 mi/mi^2, inside SCA[1]	Beneficial
Within riparian area	Beneficial
RD 0 mi/mi^2, outside SCA	Neutral
RD 0.01 – 1.00 mi/mi^2, inside SCA	Neutral
> 240 m from a human influence zone	Neutral
Area providing hiding cover	Neutral
Open area, inside SCA	Neutral
Outside riparian area	Neutral
RD 0.01 – 1.00 mi/mi^2, outside SCA	Minimal
RD 1.01 – 2.00 mi/mi^2, inside SCA	Minimal
Edge, outside SCA	Minimal
RD 1.01 – 2.00 mi/mi^2, outside SCA	Low
RD > 2.00 mi/mi^2, inside SCA	Low
120 – 240 m from a human influence zone	Low

RD > 2.00 mi/mi^2, outside SCA	Moderate
< 120 m from a human influence zone	Moderate
Open area, outside SCA	Moderate
Within a human influence zone	High

Secure Core Areas (SCA) are areas > 500 meters from open roads, or roads with motorized use restricted by a gate or a sign, and non-motorized trails receiving more than 12 parties per week. Roads with use restricted by berms, rocks, or logs could exist inside SCAs.

[1]SCA = secure core area

Table 2. Human influence zone buffer sizes, types, and danger categories (Sandstrom 1996).

Influence zone radius		Type of developed site	CEM Danger Category
Meters	**# of cells**		
60	2	Fishing access, boat launch, trailhead, Miscellaneous structure	low
120	4	Campsite, picnic site, work station, Outfitter camp, viewpoint	medium
210	7	Residence, livestock operation, Community, school, manufacturing business, church, campground, garbage dump, restaurant, summer camp, guest lodge	high

We therefore assumed that open areas have a negative affect on habitat quality only if within 500 m of an open road, a road with use restricted by a gate or a sign, or a high-use trail outside SCAs.

We used LANDSAT Thematic Mapper satellite imagery and unsupervised classification (Ma 1994) to delineate areas of hiding cover. Open cover/non-cover edges were delineated with a 30 m buffer to represent use of forest edges by wildlife. In the LZP model, open areas were classified the same as cover areas within SCAs, but were assigned a “moderate” impact when outside SCAs. Edge areas outside SCAs were assigned a “minimal” impact.

Riparian areas – Previous research has shown that riparian areas are important to wildlife such as bears and generally provide more food and security than other cover types (Mealey et al. 1977, Mace and Jonkel 1979, Servheen 1983, Craighead 1982, Aune et al. 1984, Kasworm 1985, Almack 1986). In many cases, riparian areas run perpendicular to the linear arrangement of human developments along higher-order waterways, thus facilitating wildlife movement through developed areas.

We developed a computer model to predict the occurrence of riparian areas because detailed vegetation mapping was not available in most of the LZP model evaluation areas (Sandstrom 1996). This model mapped the potential for riparian vegetation based on the slope of land adjacent to waterways. Using digital hydrography and elevation data from USGS (USGS 1987a, b), we buffered existing waterways by an amount proportional to the change in elevation out to a maximum of 210 m.

Two caveats apply to this riparian model. First, this predictive riparian model was developed for use at landscape scales and where little field mapping has occurred. Small, but important, micro-sites such as seeps were excluded because of the spatial resolution of the mapping process. The riparian model should not be considered a replacement for site-specific field mapping. Second, the model does not determine specific vegetation types within the riparian area, which may include open water, rocks, wet meadows, deciduous shrubs, and coniferous forest.

Land ownership – In the western U.S., much of the land useful for human development lies within valley bottoms. Here, soils and terrain are suited for agriculture and transportation systems, and water is available for drinking and irrigation. These desirable and productive valley bottoms are primarily privately owned. However, because of their linear nature, they serve to further fragment remaining wildlife habitat. Thus, land ownership patterns can indicate areas of habitat fragmentation. Land ownership information was not directly incorporated into the LZP model, but was used to help identify areas where linkage zone opportunities might best be preserved. Digital land ownership files denoting either publicly or privately owned lands were obtained from the Wildlife Spatial Analysis Lab at the University of Montana, Missoula.

Highway structure and volume – The LZP model does not include highway features, form, or traffic volume in its scored map output. Highways are important habitat fragmentation factors and must be accounted for in any management scheme that seeks to facilitate linkage for wildlife species. The purpose of the LZP model is to identify areas where human activity levels still allow some opportunity for movement. Getting wildlife across highways within linkage zone areas is important and recommendations on this issue are detailed in the section on management of linkage zones.

Final LZP model score – Each of the 4 input data layers (roads, developed sites, cover conditions, riparian areas) were combined into one new layer displaying the combined impact of each of these factors on habitat quality. The combined scores were then divided into 4 categories based upon subjective evaluation. In general, to be considered in the “minimal” combined impact category, the pixel had to have “neutral” or “beneficial” impact values for all 4 individual layers, or only one condition have a "minimal" or "low" impact value. To be considered in the "low" combined impact category, 2 conditions could be in the "minimal" or "low" category, or 1 condition in the "minimal" or "low" category and/or 1 condition in the "moderate" category while the others had to be "beneficial" or "neutral". To be considered in the "moderate" or "high" combined impact category, individual impact values had to be different combinations of "low", "moderate", and "high" impact values. When interpreting these combinations it is important to acknowledge how different human impacts interact with each other. For example, residences in valley bottoms are nearly always associated with some level of road density and often with open areas. The model is indirectly driven by presence of developed sites, not because they were given the highest impact category, but because developed sites almost always occur in association with roads and open areas of limited visual cover (Table 1).

Delineation of linkage zones – Examining the maps showing combined impact scores allowed identification of Linkage Zones. The goal was to locate areas where wildlife could move between large blocks of habitat on public lands with the least conflict with people. To qualify as a linkage zone, an area had to be within the "minimal" or "low" combined impact categories and span an area between the large blocks of habitat on federal lands in a continuous fashion. Single, small areas in the "moderate" or "high" combined impact category surrounded by areas in the "minimal" and "low" combined impact categories (usually lone developed sites surrounded by

A note on the use of linkage zone maps

The model used here predicts where wildlife can successfully move between the large blocks of public land in the northern Rocky Mountains. This prediction is based on the assumption that movement is most likely to be successful where human activity is least. This does not mean that wildlife species will not try to cross in other areas. The linkage zone concept is based on maintaining and enhancing movement possibilities in areas where such movement is most likely to be successful – the linkage zones.

forested areas) could also be included in linkage zones. Extensive areas within the "moderate" and "high" combined impact categories were excluded as linkage zones. Such areas were usually within human influence zones. To facilitate identification of linkage zones, developed corridors were displayed as yellow/black graphics, where yellow represented "low" and "minimal" combined impact categories and black represented "moderate" and "high" combined impact categories. LZP model outputs were also displayed as 3D surfaces viewed obliquely, thus giving the reader a "birds-eye" view of potential linkage zones.

Results

Each of the linkage zone evaluation areas had different amounts of habitat fragmentation, thus precluding movement between areas to varying degrees. Each evaluation area will be discussed separately. However, some common themes emerged. As stated in the introduction, most development occurred on private lands in valley bottoms. These developments generally were within human influence zones and thus ascribed "moderate" to "high" combined impact categories. Most of the public lands fell within the "minimal" or "low" combined impact categories. Some areas have a "moderate" score due to the presence of clearcuts and high road densities, or due to

The importance of Lolo Pass and Lookout Pass to north-south carnivore linkage

- Lolo Pass and Lookout Pass are the only mountain passes with high-elevation habitat between the 5,600 square mile Selway-Bitterroot and Frank Church Wilderness areas and habitats to the north
- Lookout Pass is bisected by I-90
- Wildlife that prefer high elevation habitats may funnel through such mountain passes to move across the landscape, but we do not know enough about these species to say these are the only areas they may cross
- Developments in such mountain passes may have special impacts on certain species due their location but existing information on use of such areas is minimal
- The potential of a bottleneck effect on wildlife may be especially important in such mountain passes

presence of a recreation site. Public lands scored as "moderate" were discontinuously distributed across the landscape, whereas private lands scored as "moderate" or "high" had a linear distribution along higher order waterways or primary transportation systems.

Cabinet/Yaak to Bitterroot

The most severe habitat fragmentation between the Cabinet/Yaak and Bitterroot ecosystems occurs along Montana Highway 200 between Plains, Montana and the Idaho border. Some fragmentation also occurs along Interstate 90 (I-90), from east of Superior, Montana to Lookout Pass (Figure 4), but this is mostly limited to the town sites along the route as most land adjacent to I-90 in this area is in Federal ownership. Most remaining lands along the Interstate highway were "minimal" or "low" categories and did not appear to be an impediment to linkage, except for the fact that a four lane interstate highway runs through these areas. Closer inspection of the highway corridors revealed that fracture was nearly complete between Plains and Thompson Falls (Figure 5B), and between Thompson Falls, Montana and the Idaho border (Figure 5A). Opportunities for wildlife to get across Highway 200 are limited to a few locations at present. Linear developments along the Clark Fork River were nearly continuous along this corridor, and thus represented an impediment to linkage (Figures 6, 7). In addition, development of private lands (Figure 8) is proceeding at a rapid pace in this area with new homes appearing all through this valley. The Clark Fork River canyon between Plains and Thompson Falls, Montana is an area where private lands in this river valley are narrow (Figure 9).

The I-90 corridor between Superior, Montana and Lookout Pass has opportunity for linkage through habitats with "minimal" and "low" combined impact category rankings (Figure 5C). The only possible linkage area between Superior and St. Regis was a narrow undeveloped area southeast of St. Regis between Red Hill and Cold Cr. (Figure 10). Little development has occurred in the I-90 corridor between St. Regis and Deborgia, offering ample opportunity for linkage (Figures 11 and 12). Continuing development is occurring around the communities of Deborgia and Saltese (Figures 5C, 11).

Cabinet/Yaak to Selkirks

Severe habitat fragmentation has occurred in the broad valley between Colburn and the Idaho - Canada border (Figure 13). Additional fragmentation is occurring in the area surrounding Priest Lake, Idaho. The area along US Highway 95 and Idaho Highway 1, between Bonners Ferry and the Canadian border, had extensive development throughout the valley and there appeared to be limited opportunity for safe crossing (Figure 14A). The area along US Highway 95 between Bonners Ferry and Colburn was similarly developed, however linkage could occur in the narrowly developed area near McArthur Lake (Figures 14B, 15, 16), although human influence zones were close to this

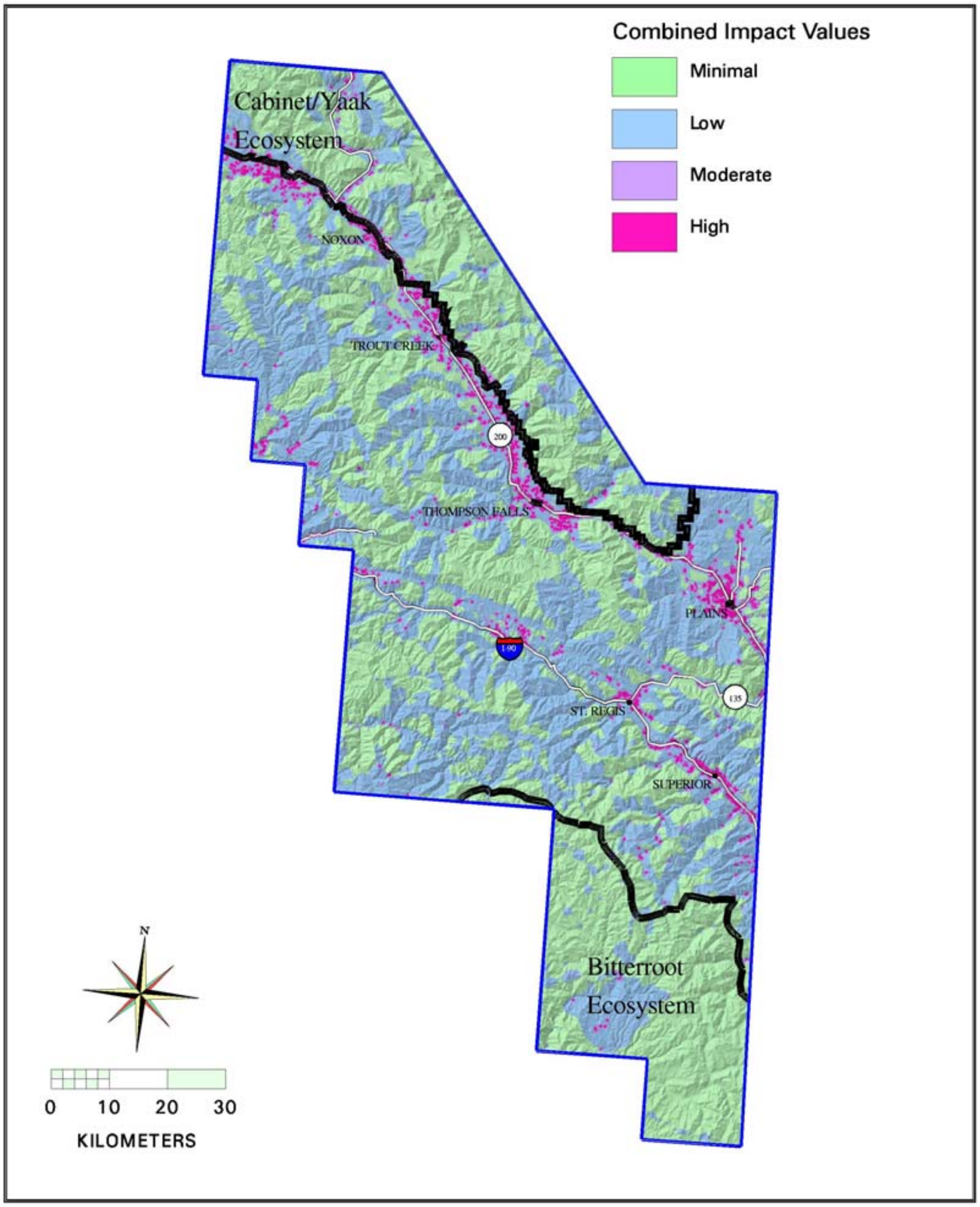


Figure 3. Linkage Zone Prediction Model output for the Cabinet/Yaak to Bitterroot Ecosystem evaluation area.

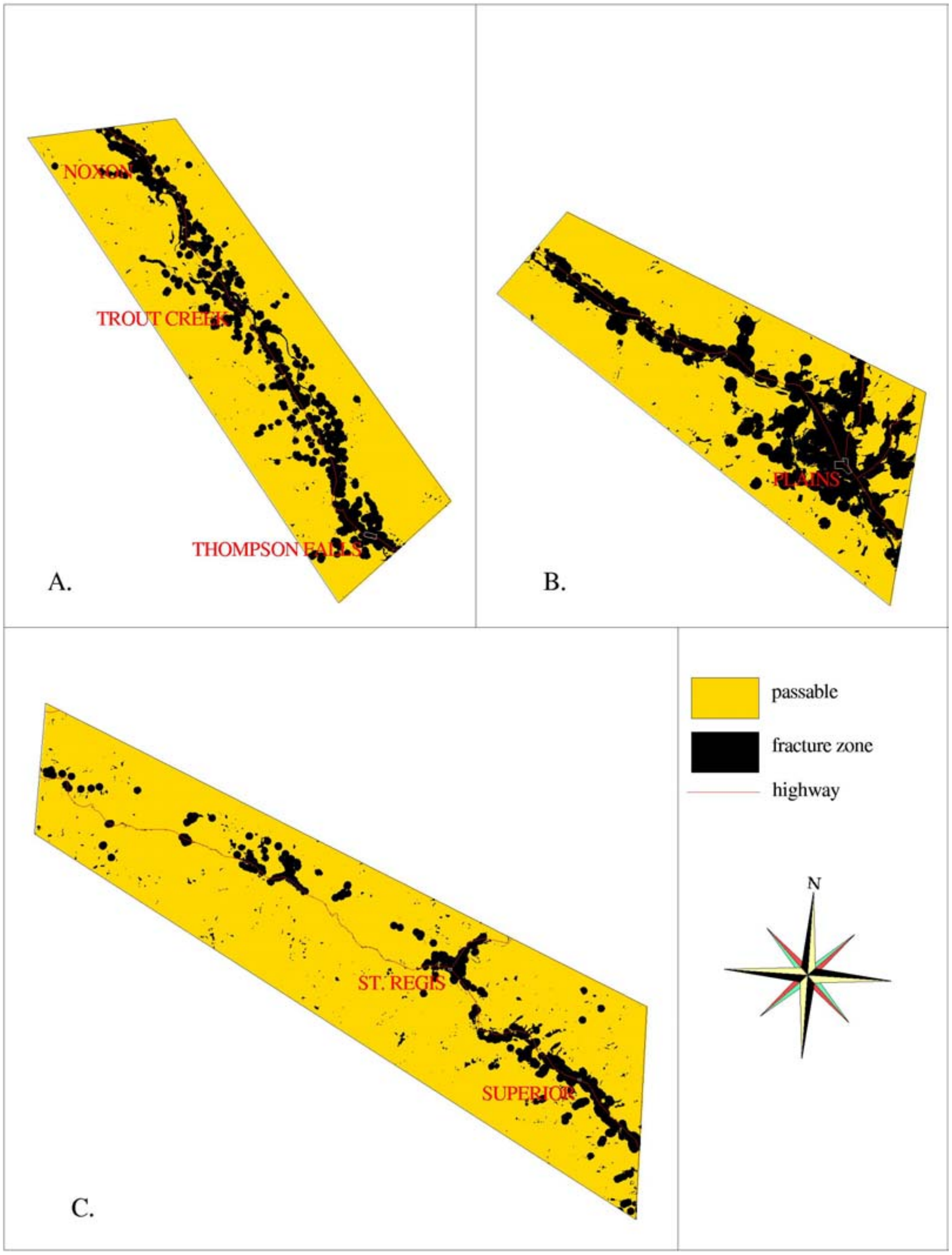


Figure 4. Linkage Zone Prediction Model output for mountain valleys within the Cabinet/Yaak to Bitterroot linkage zone evaluation area. Yellow is minimal impact. Black is moderate to high impact. A. Hwy 200 - Thompson Falls to Noxon. B. Hwy 200 - Plains to Thompson Falls. C. I-90 – Superior to Lookout Pass.

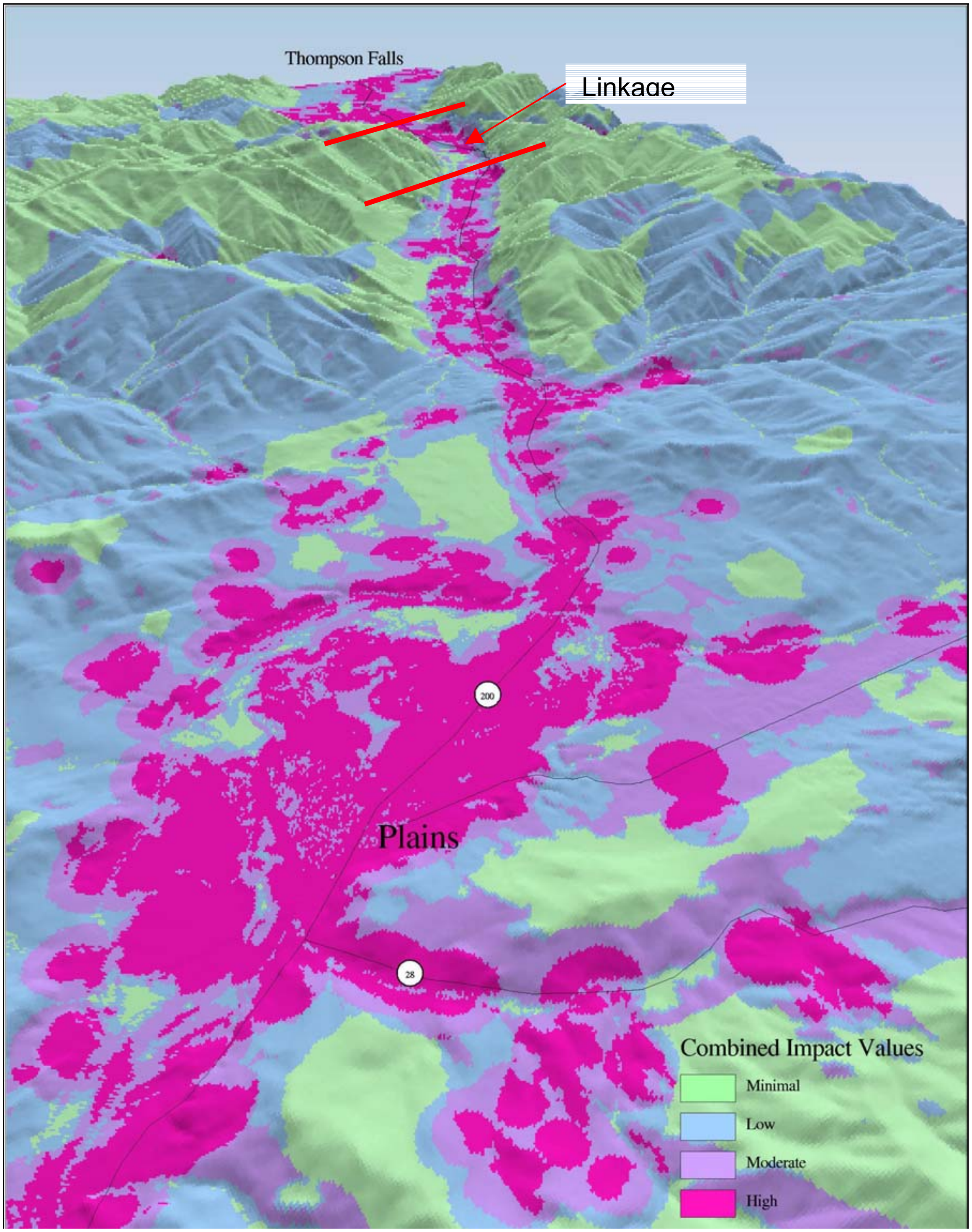


Figure 5. Landscape view of Linkage Zone Prediction Model output looking northwest from Plains to Thompson Falls, Montana along Highway 200.

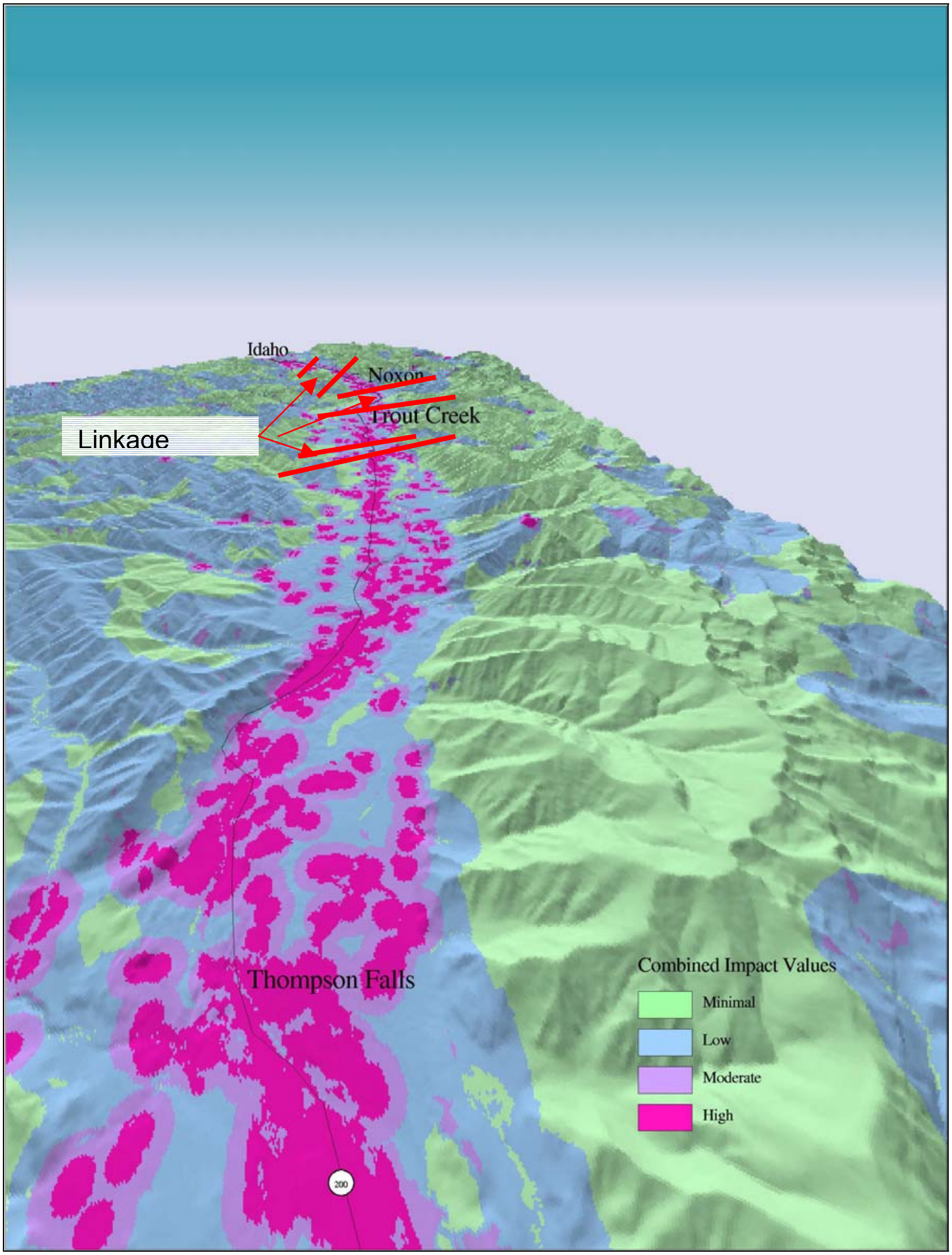


Figure 6. Landscape view of Linkage Zone Prediction Model output from Thompson Falls, Montana northwest along Highway 200 to the Idaho border.

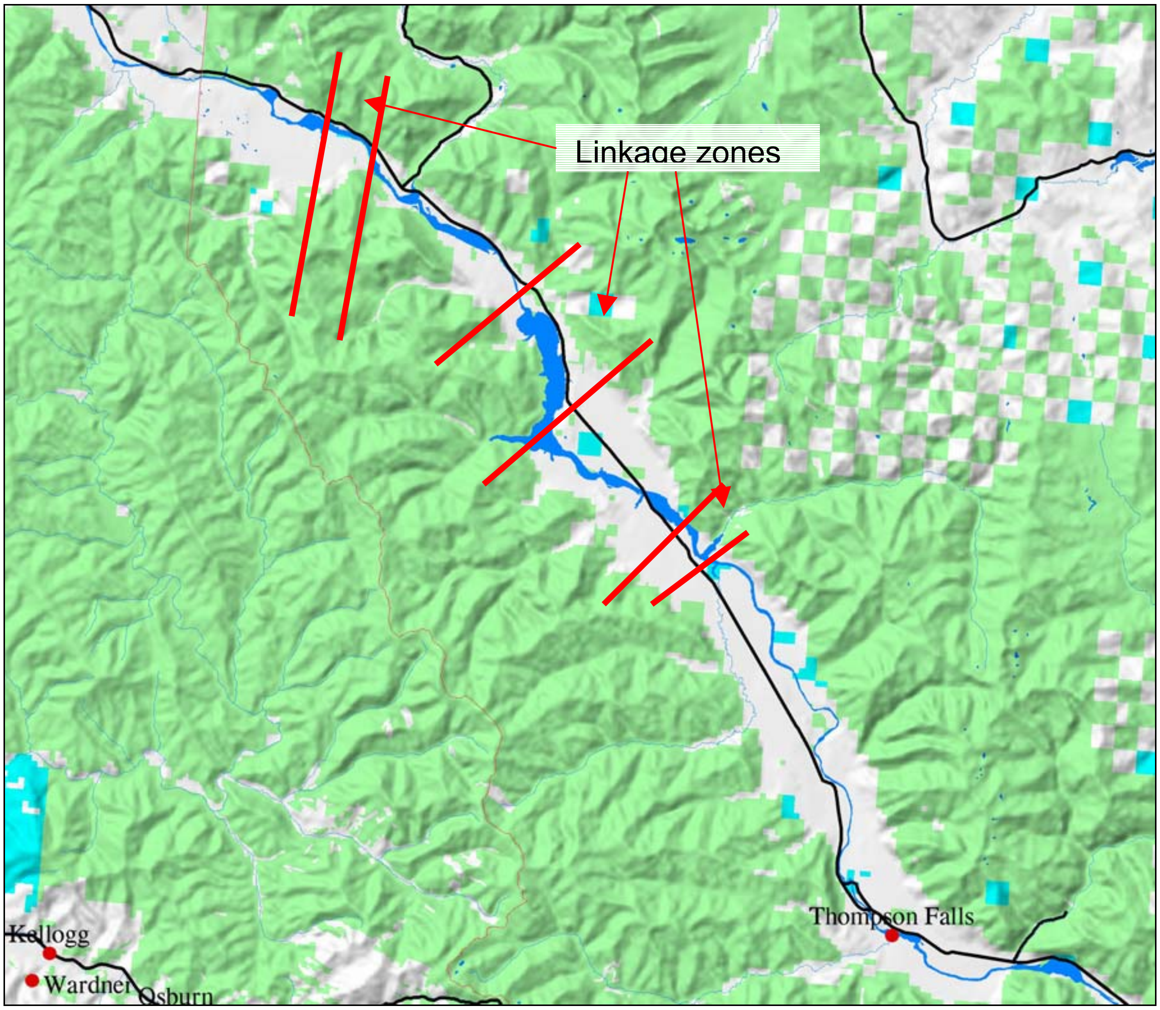


Figure 7. Land ownership along Highway 200 between Thompson Falls and the Idaho line. Green is USFS, blue is state, white is private.

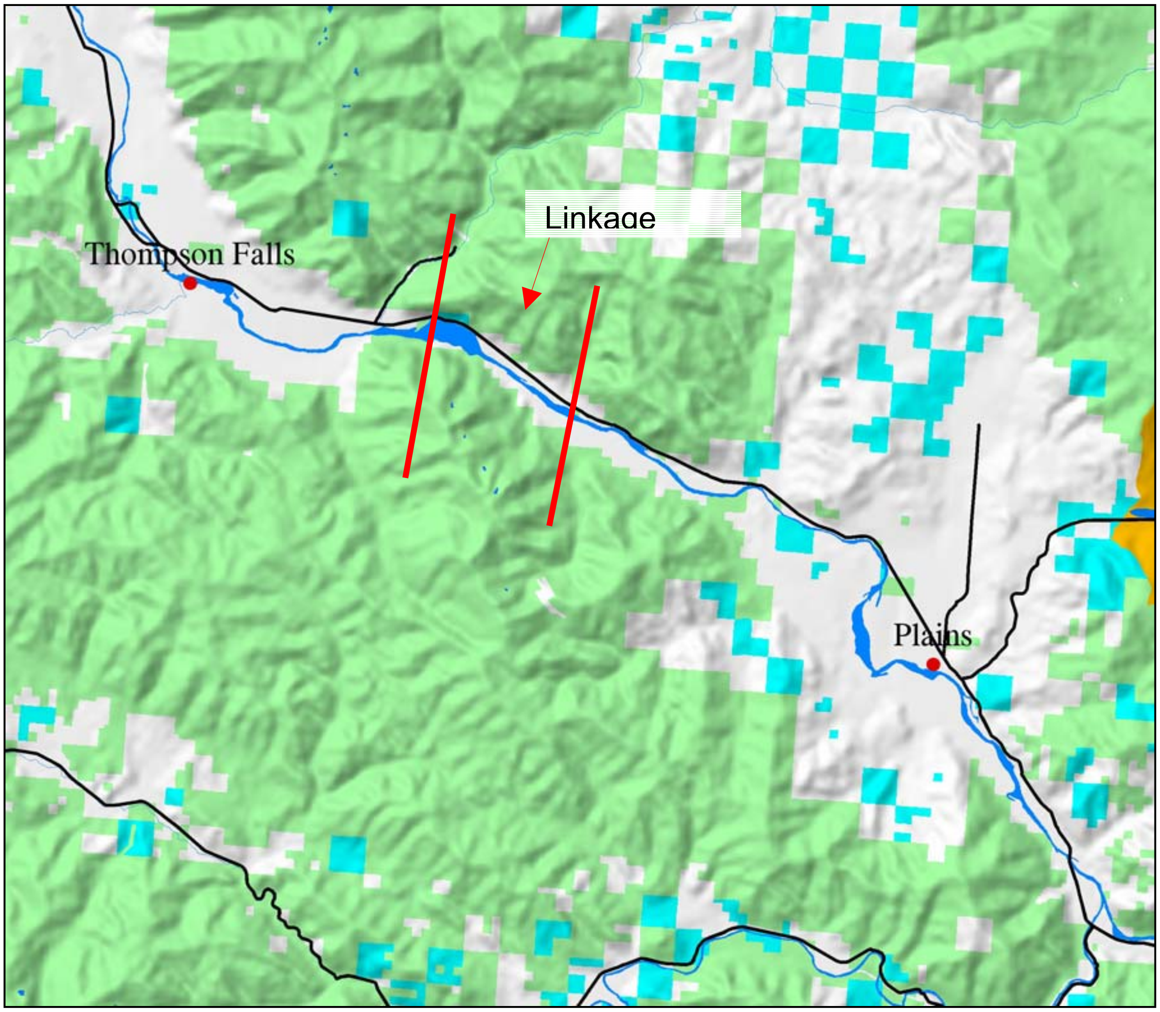


Figure 8. Land ownership between Plains and Thompson Falls, Montana. Green is USFS, blue is state, white is private.

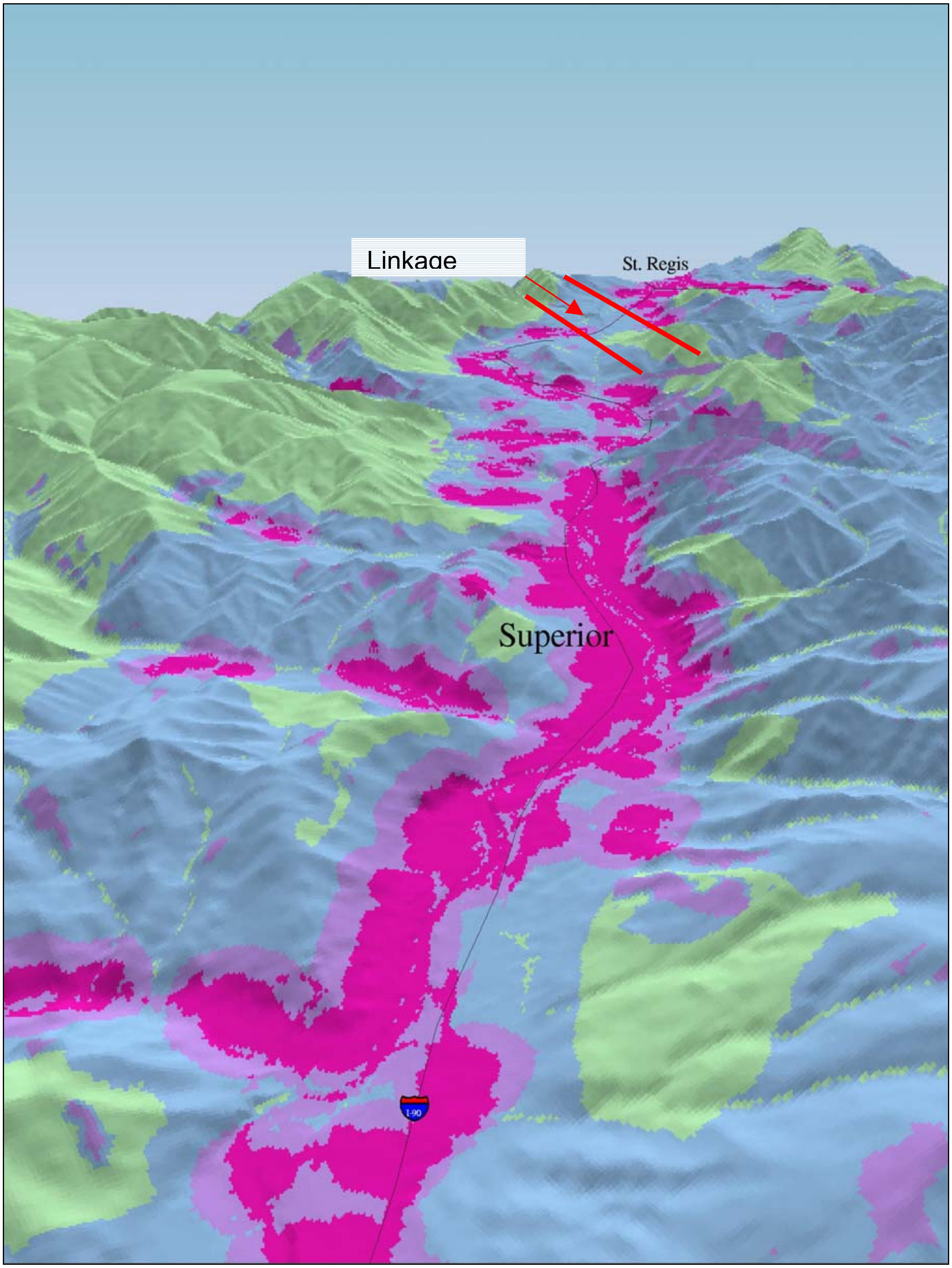


Figure 9. Landscape view of Linkage Zone Prediction Model output looking northwest from Superior to St. Regis, Montana along I-90.

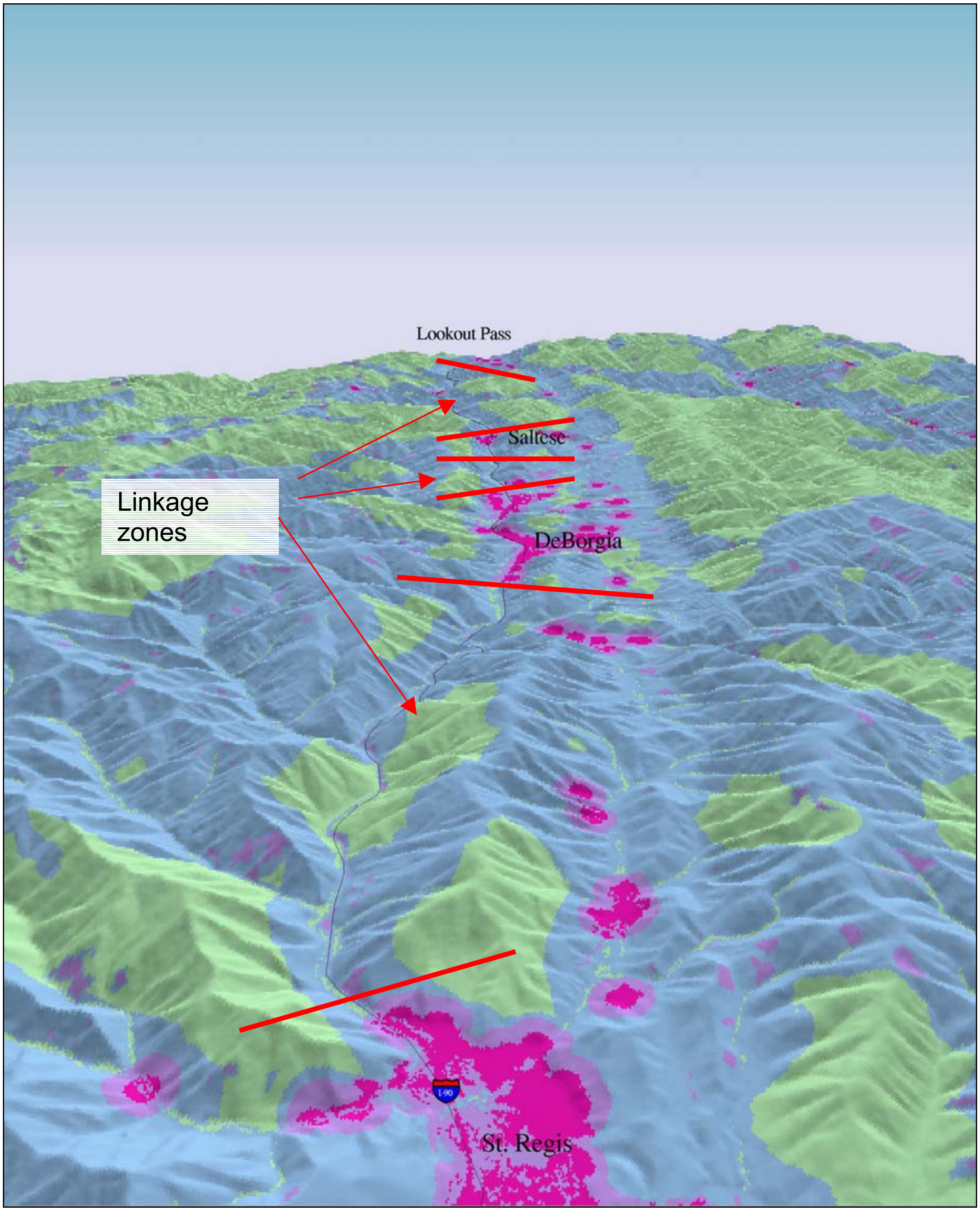


Figure 10. Landscape view of Linkage Zone Prediction Model output looking northwest from St. Regis, Montana to Lookout Pass along I-90. This is a critical linkage connection, the success of which will be determined by the permeability of the highway and what Montana DOT does to address linkage in this area.

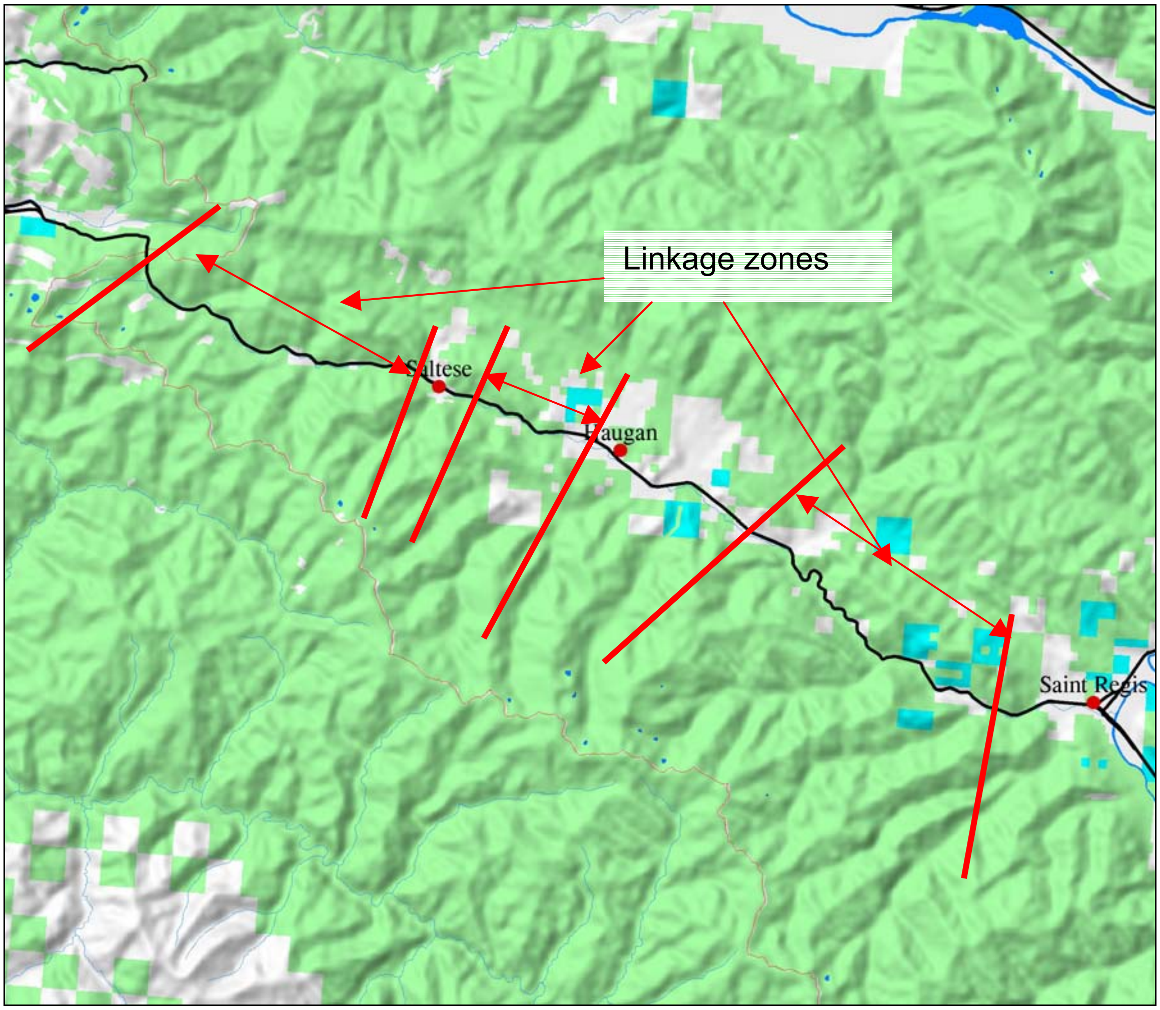


Figure 11. Land ownership and linkage zones along I-90 from St. Regis, Montana to Lookout Pass on the Idaho line. Linkage zones are within the red arrow areas. Green is USFS, blue is state, white is private.

McArthur Lake site. Few, if any, other opportunities exist for crossing this valley (Figures 17, 18).

Development around Priest Lake will force wildlife wishing to move east into the Cabinet/Yaak around to the north or south of the lake (Figures 14C and 19). The safest route would be around to the north of Priest Lake where little human development occurs and the terrain is more rugged (Figures 19, 20).

NCDE to Bitterroots

Most fragmentation within this evaluation area occurred along the I-90 corridor between Missoula and Superior, Montana, and along US Highway 93 North of Missoula from Evaro Hill to Ravalli Hill. Missoula is a rapidly growing city and suburban development has been rapidly spreading west and north along these major highway corridors. Development was most intense along I-90, east and west of Alberton (Figures 21, 22A, B, 23, 24). Rural subdivision has also been occurring in the Ninemile valley, which threatens to further fragment the possible linkage area between the Rattlesnake Mountains east of Highway 93 and the Bitterroot area south of I-90 (Figure 23).

The only intact linkage between the NCDE and the Bitterroots is along Highway 93 in the Evaro Hill area. Considerations for maintaining linkage in this area were discussed by Mietz (1994). Areas further north of this evaluation area are close to the Highway 93 communities of Arlee, Ravalli, and St. Ignatius. Intensive human development in the Mission Valley north of St. Ignatius likely prohibits any movement south and west to any extent toward the Bitterroot wilderness areas (Figure 3). Those animals that do move from the NCDE into the Bitterroot wilderness areas - the Selway Bitterroot Wilderness and Frank Church-River of No Return Wilderness - must cross US 93, I-90, and US 12.

In order to cross I-90, wildlife might use the Red Hill/Cold Cr. crossing southeast of St. Regis, suggested in the Cabinets to Bitterroots section (Figure 24, 26), or use one of 3 linkage areas between Superior and Frenchtown. The first is between Cougar Cr. and First Cr., and the second between Sunrise

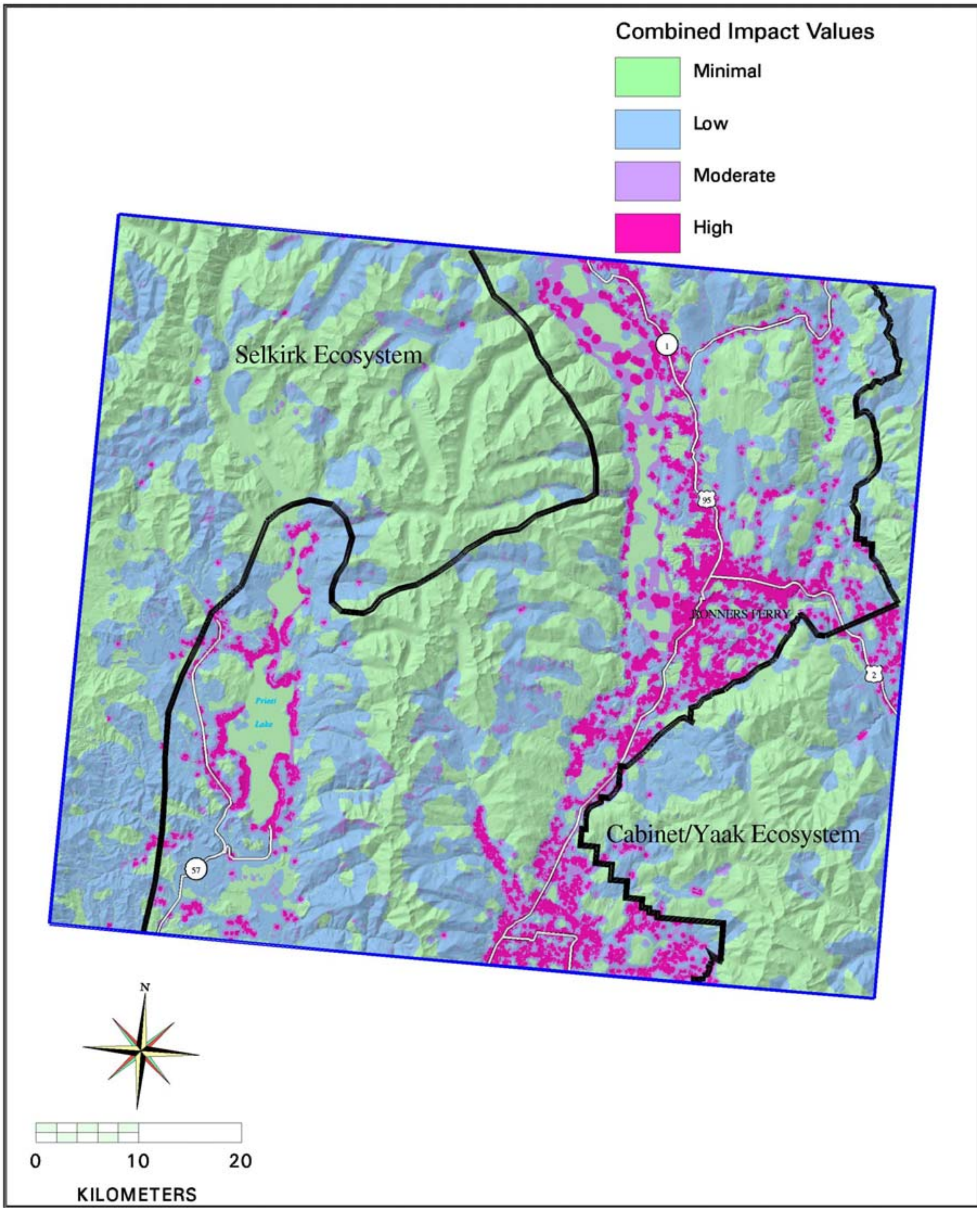


Figure 12. Linkage Zone Prediction Model output for the Cabinet/Yaak to Selkirk Ecosystems evaluation area.

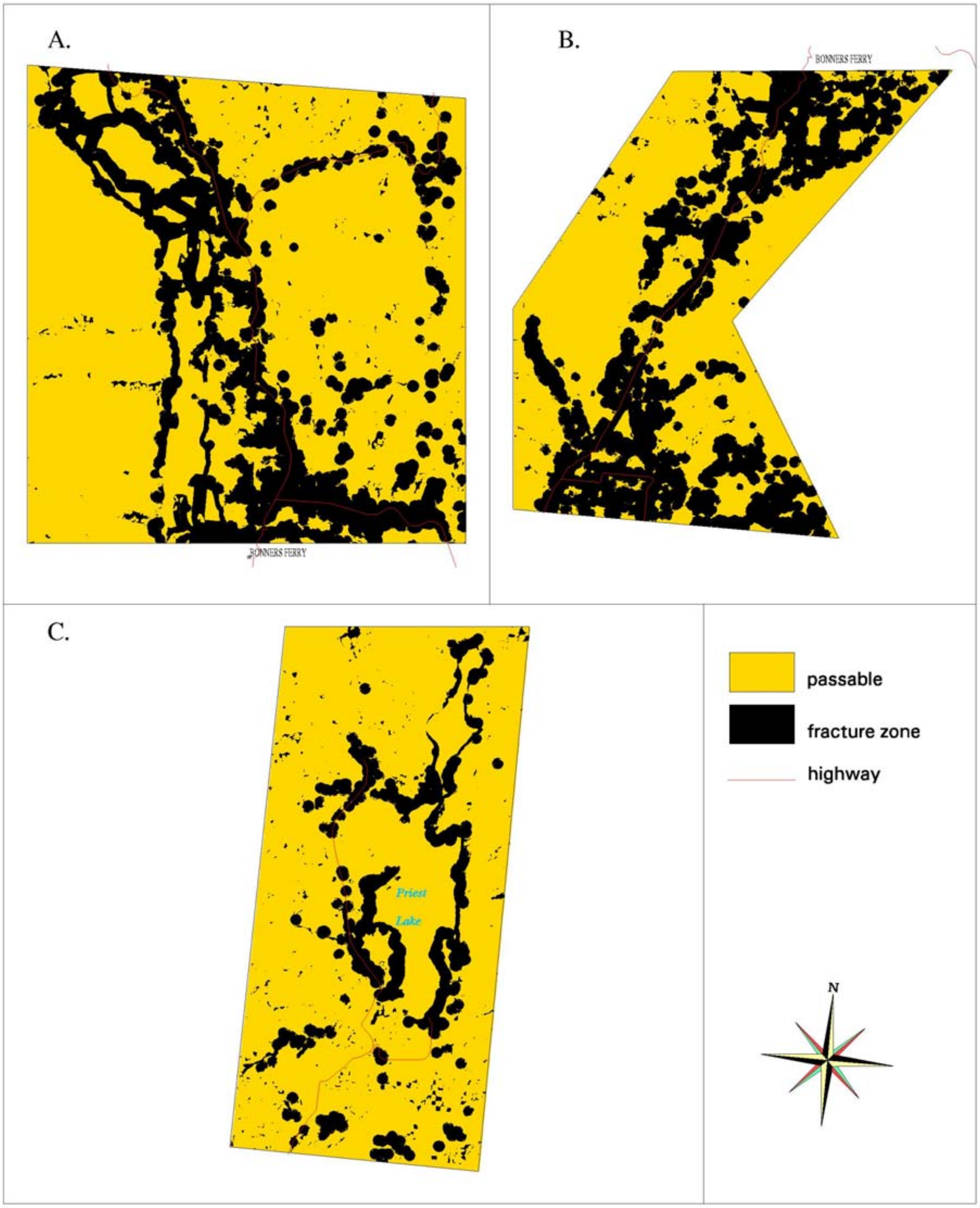


Figure 13. Linkage Zone Prediction Model output for mountain valleys within the Cabinet/Yaak to Selkirk linkage zone evaluation area. Yellow is minimal impact. Black is moderate to high impact. A. Hwy 95 - Bonners Ferry, Idaho to the Canadian border. B. Hwy 95 - Colburn to Bonners Ferry, Idaho. C. Priest Lake area in Idaho.

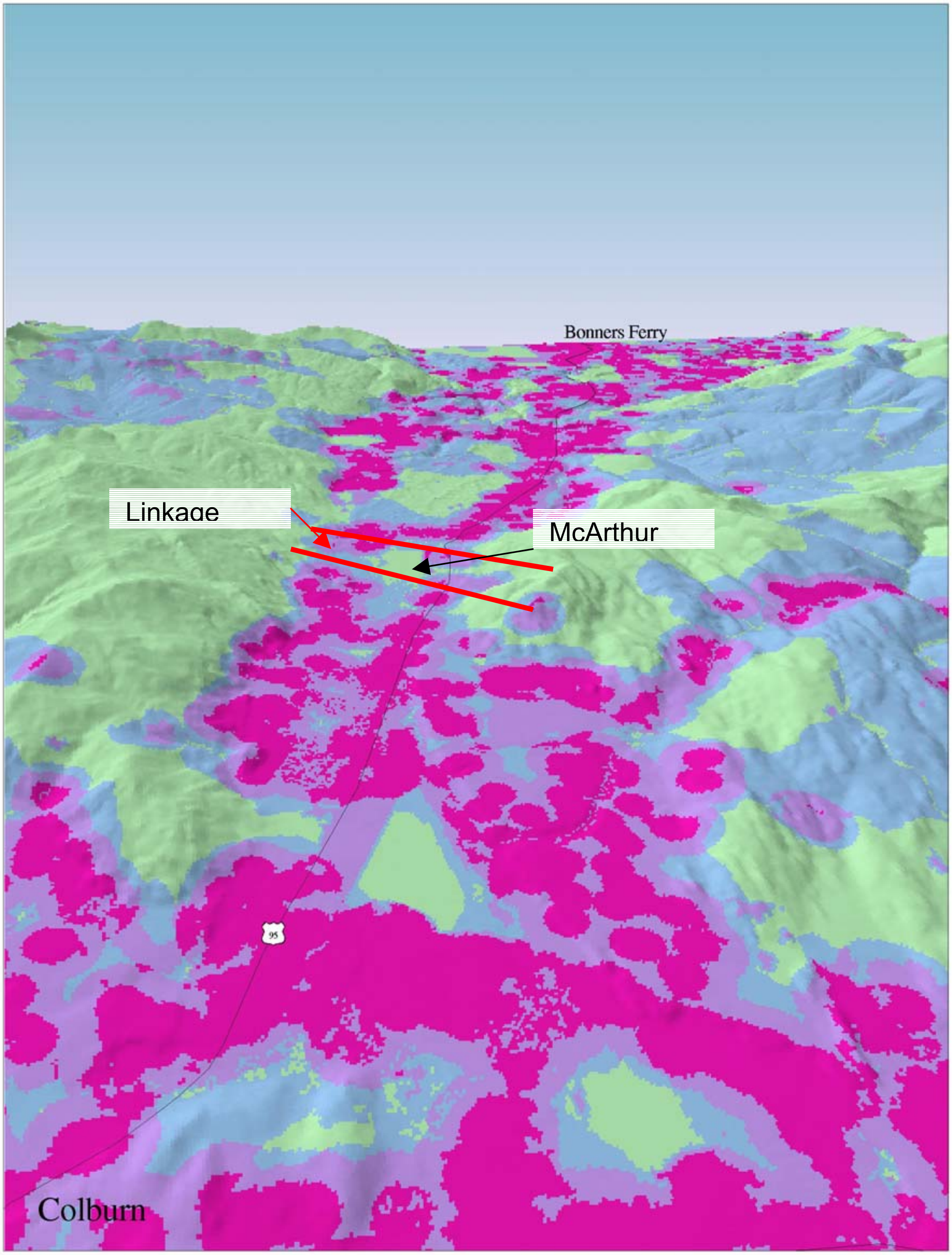


Figure 14. Landscape view of Linkage Zone Prediction Model output looking northeast from Colburn to Bonners Ferry, Idaho along Highway 95.

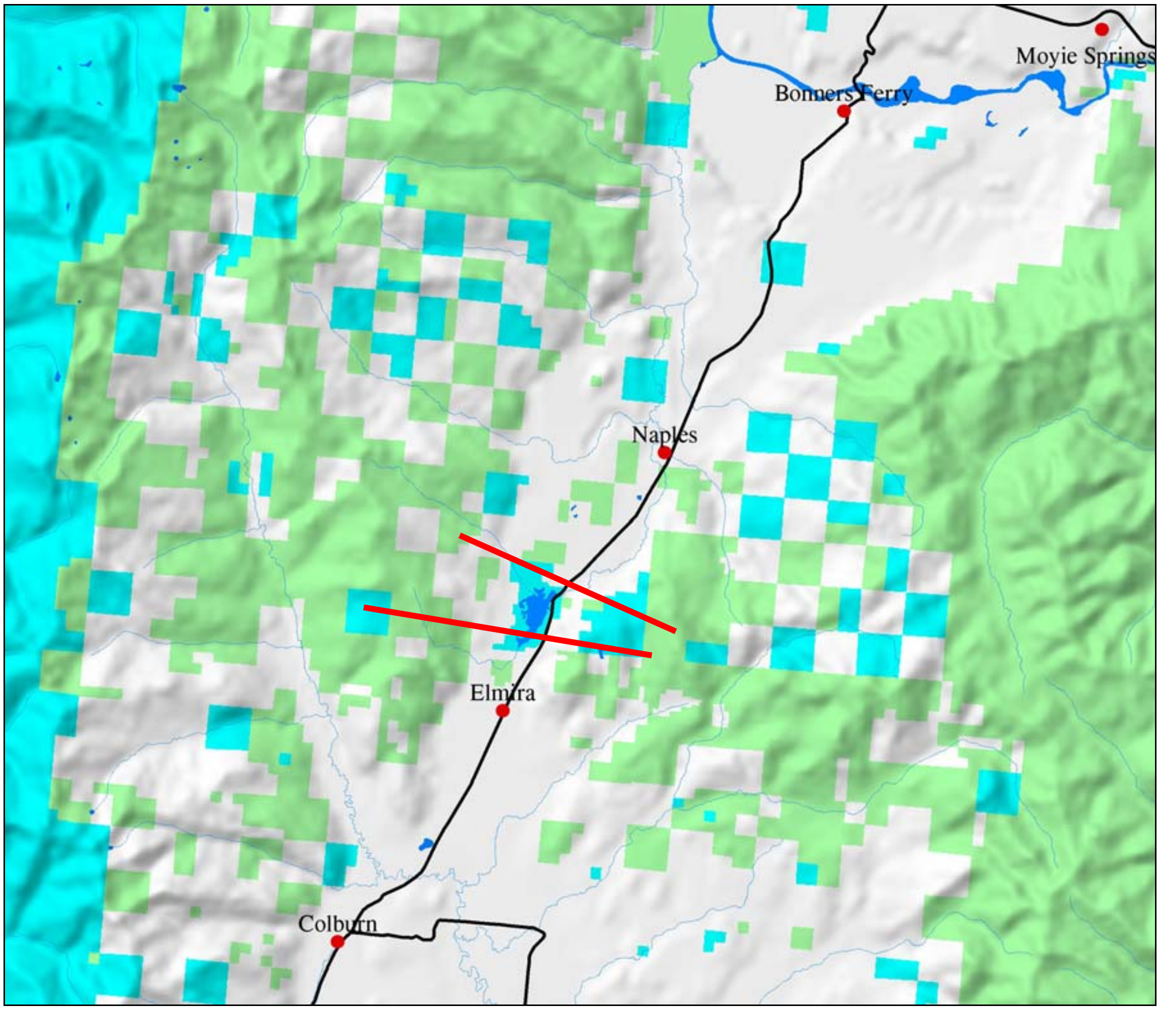


Figure15. Land ownership along US 95 between Colburn and Bonners Ferry, Idaho. Green is USFS, blue is state, white is private.

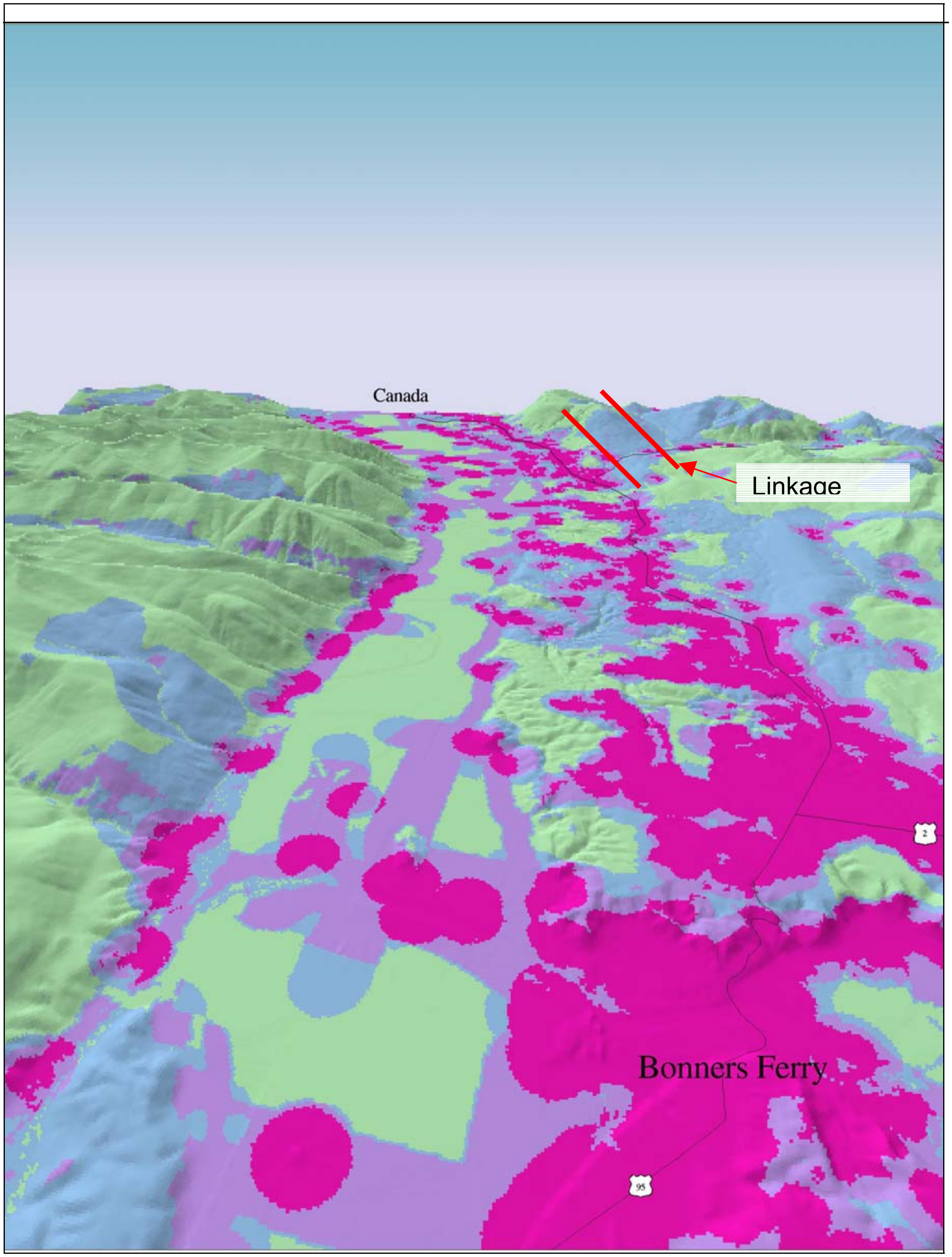


Figure 16. Landscape view of Linkage Zone Prediction Model output looking north from Bonners Ferry, Idaho to the Canadian border along Highway 95.

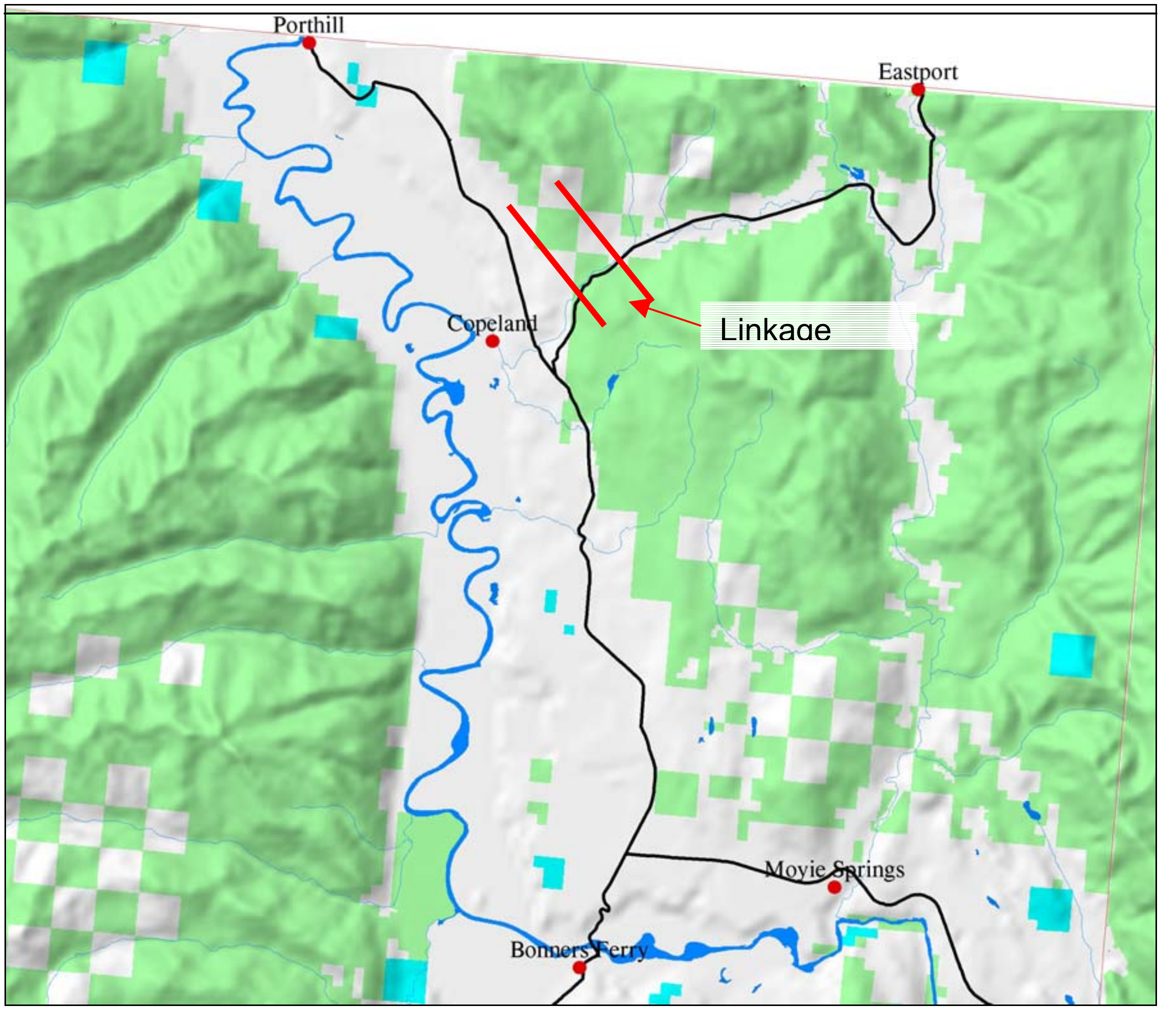


Figure 17. Land ownership along US 95 between Bonners Ferry, Idaho and Canada. Green is USFS, blue is state, white is private.

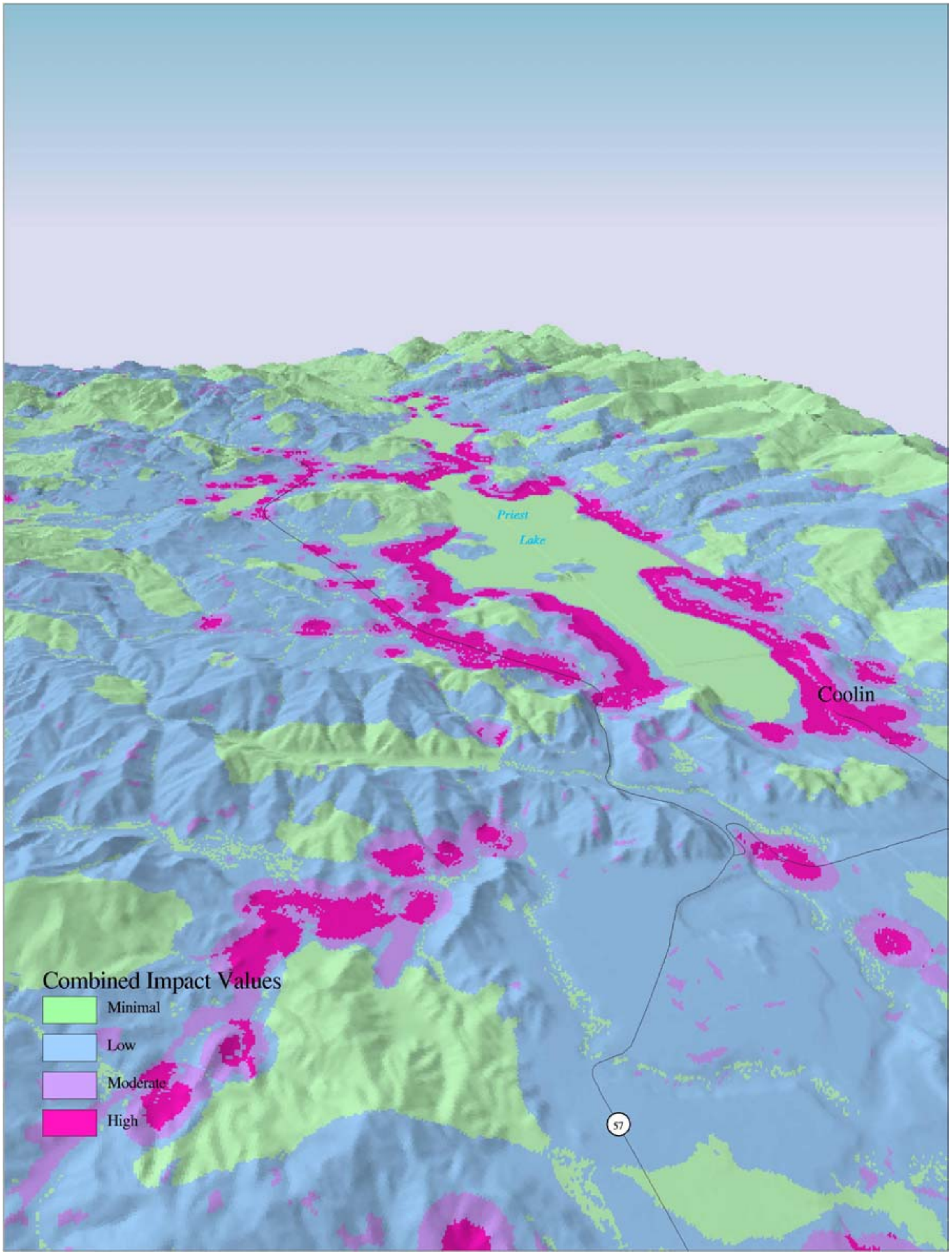


Figure 18. Linkage Zone Prediction Model output of the Priest Lake, Idaho area.

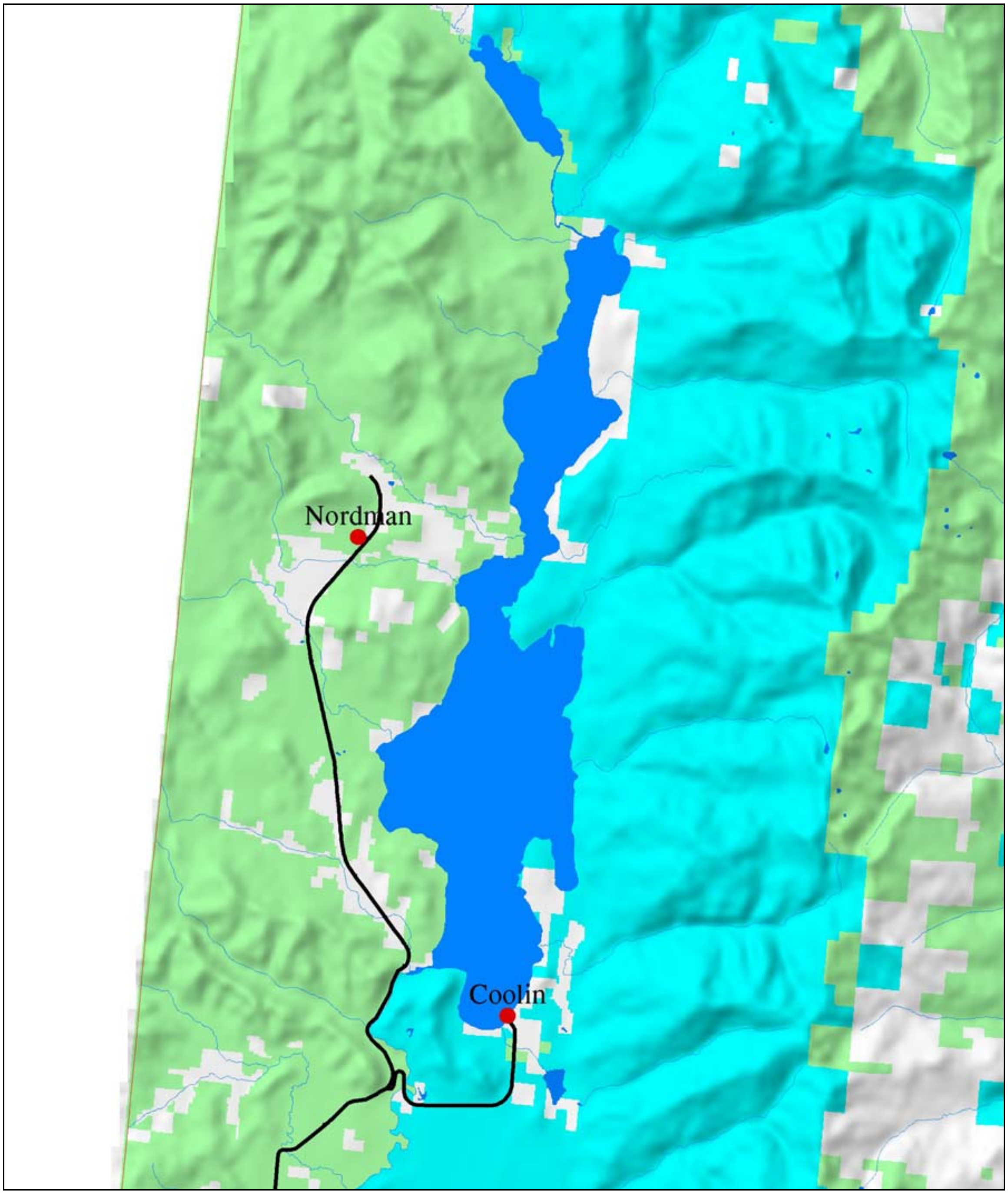


Figure 19. Land ownership around Priest Lake, Idaho. Green is USFS, blue is state, white is private.

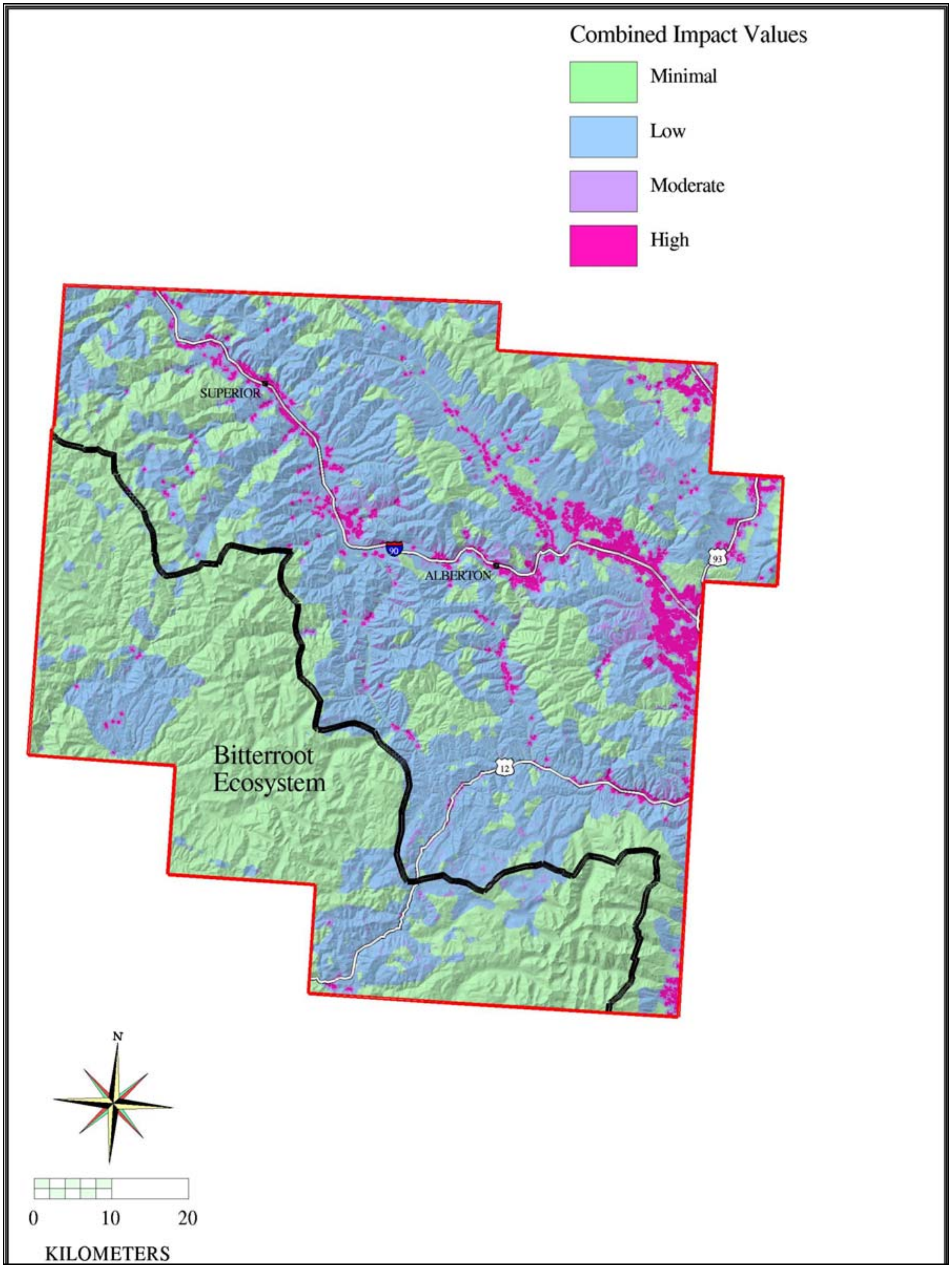


Figure 20. Linkage Zone Prediction Model output for the NCDE to Bitterroot ecosystem evaluation area.

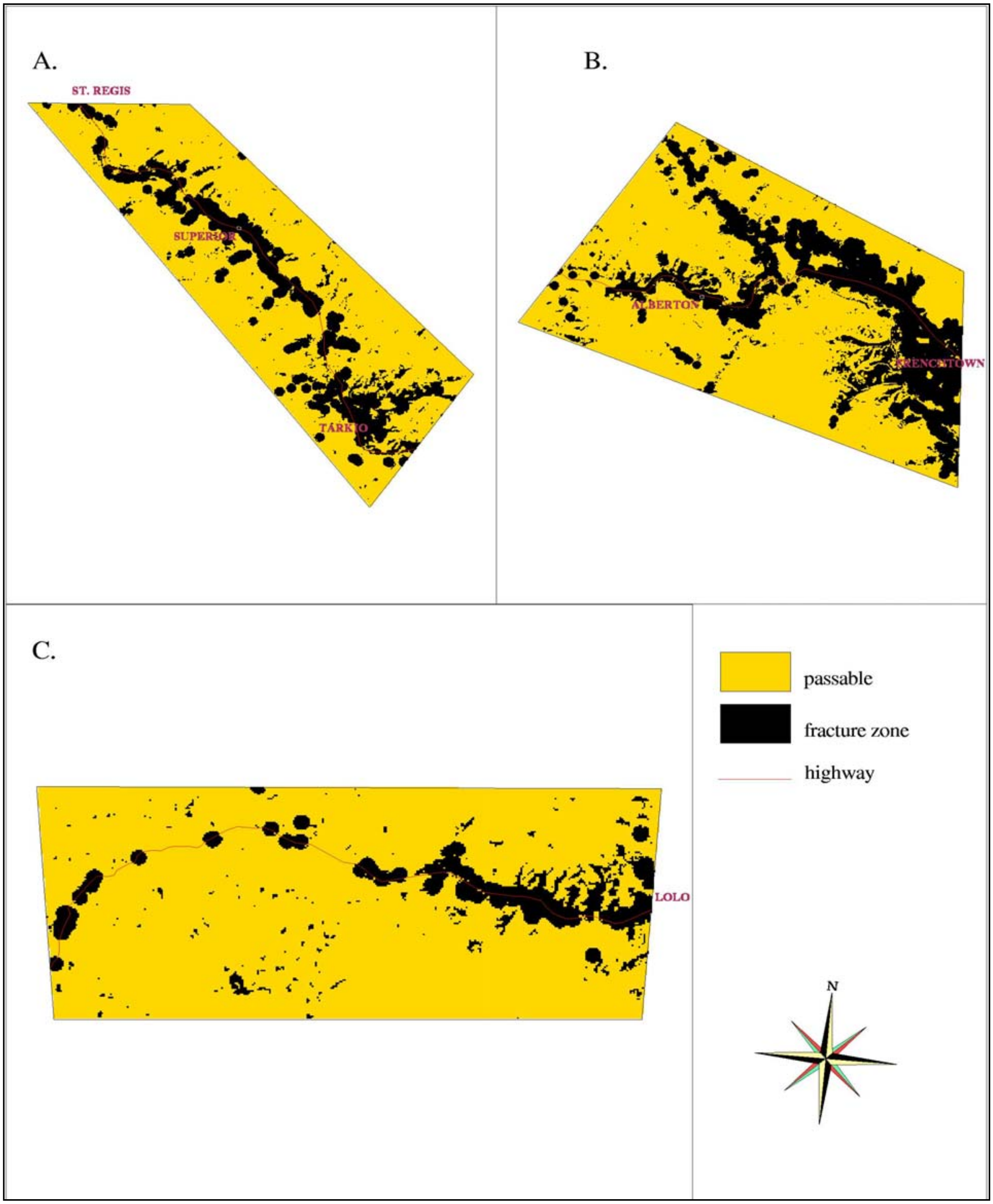


Figure 21. Linkage Zone Prediction Model output for mountain valleys in the NCDE to Bitterroot evaluation area. Yellow is minimal impact. Black is moderate to high impact. A. I-90 – Tarkio to St. Regis, Montana. B. I-90 – Frenchtown to Alberton, Montana. C. Highway 12 – Lolo to Lolo Hot Springs, Montana.

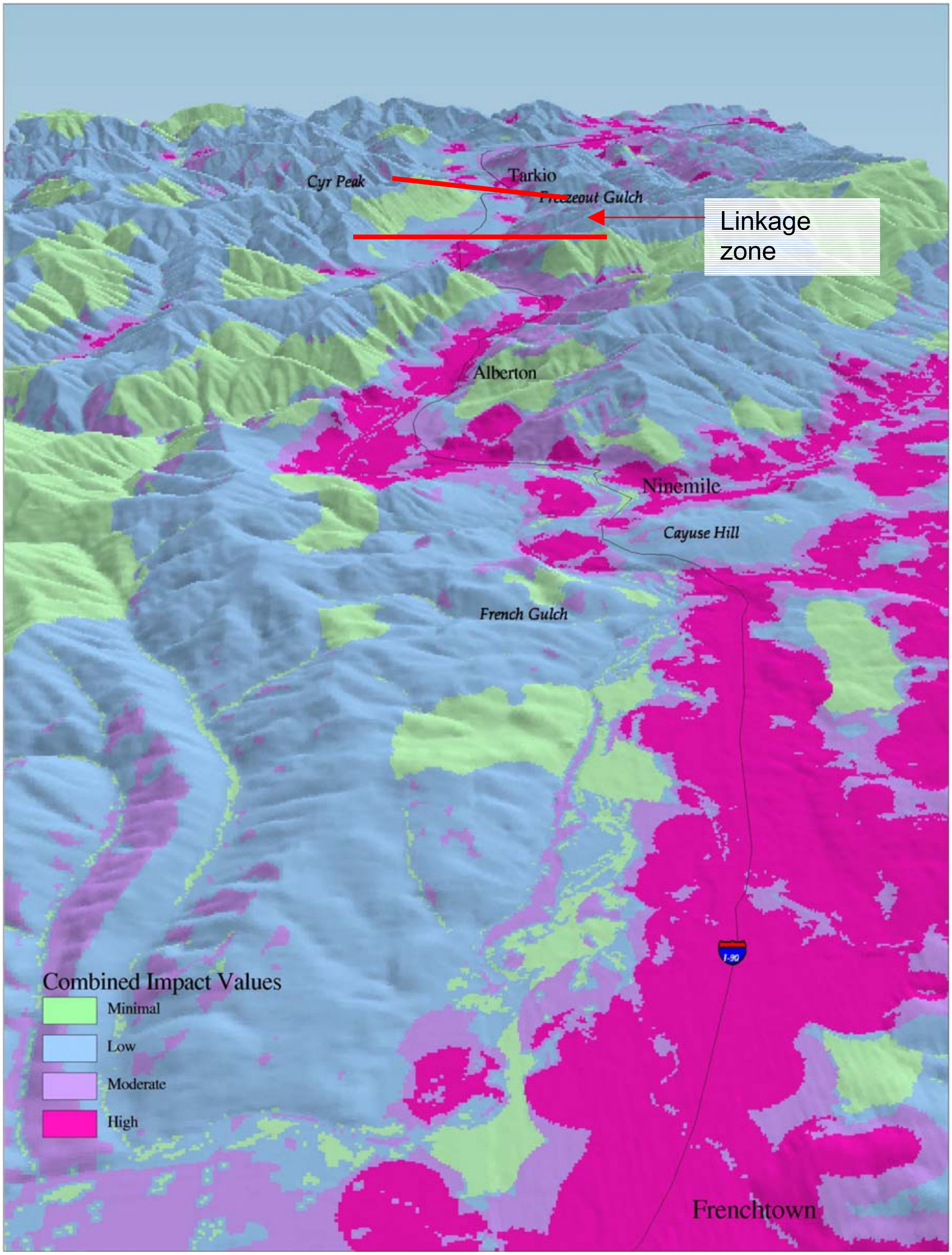


Figure 22. Landscape view of Linkage Zone Prediction Model output looking west from Frenchtown to Tarkio, Montana.

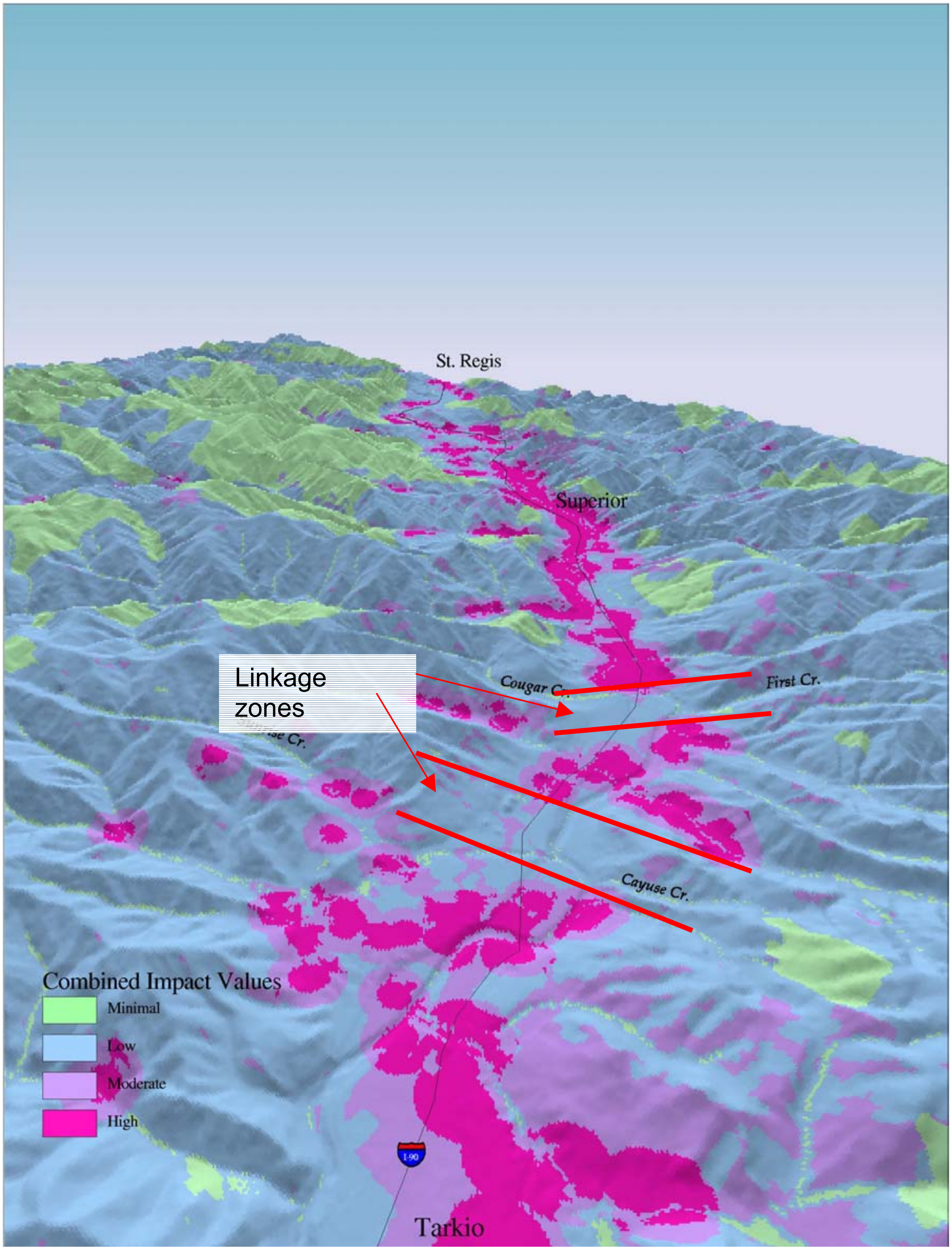


Figure 23. Landscape view of Linkage Zone Prediction Model output from Tarkio to St. Regis, Montana along I-90.

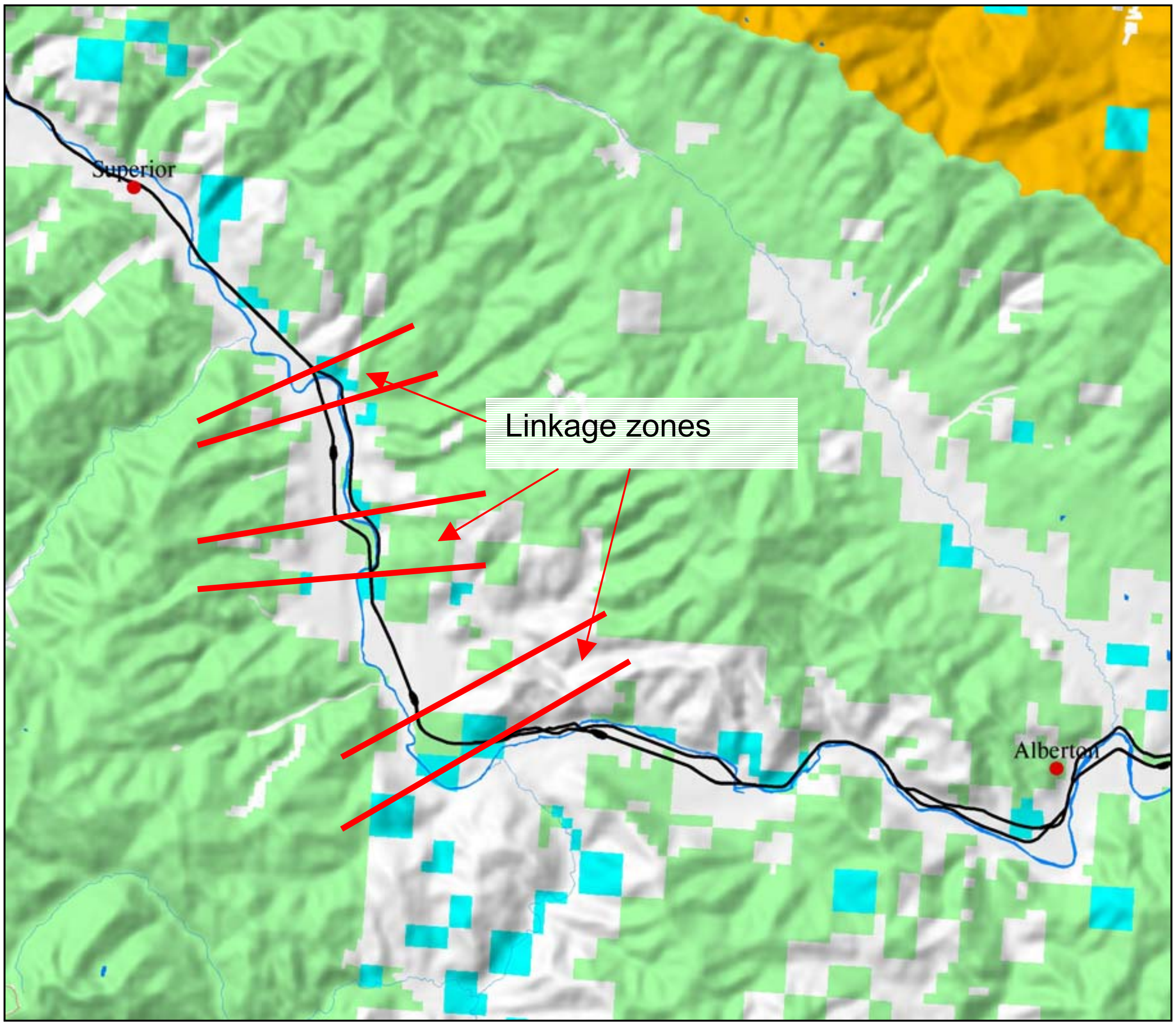


Figure 24. Land ownership along I-90 between Alberton and Superior, Montana. Green is USFS, blue is state, white is private.

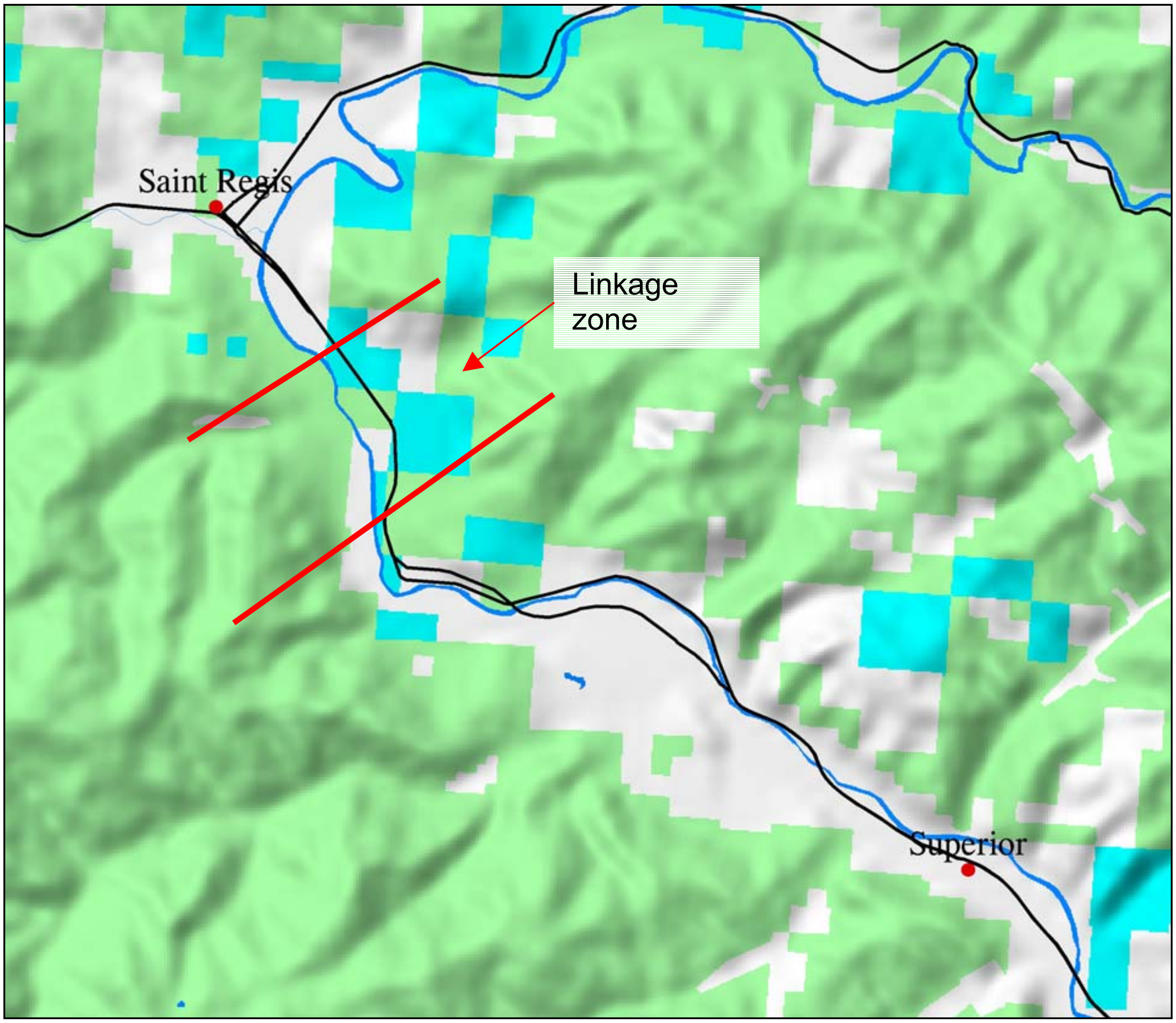


Figure 25. Land ownership along I-90 between Superior and St. Regis, Montana. Green is USFS, blue is state, white is private.

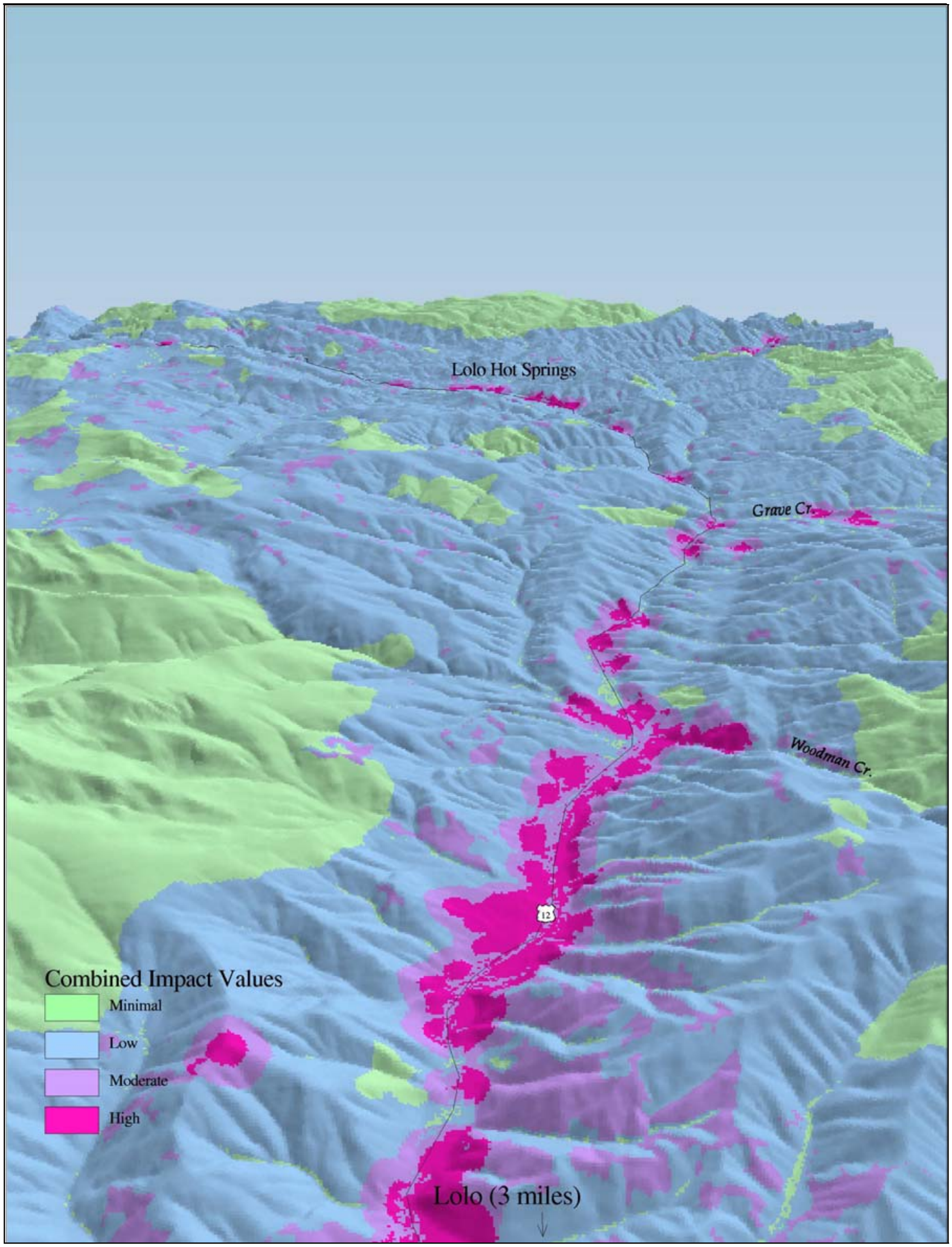


Figure 26. Landscape view of Linkage Zone Prediction Model output looking west from Lolo to Lolo Hot Springs, Montana.

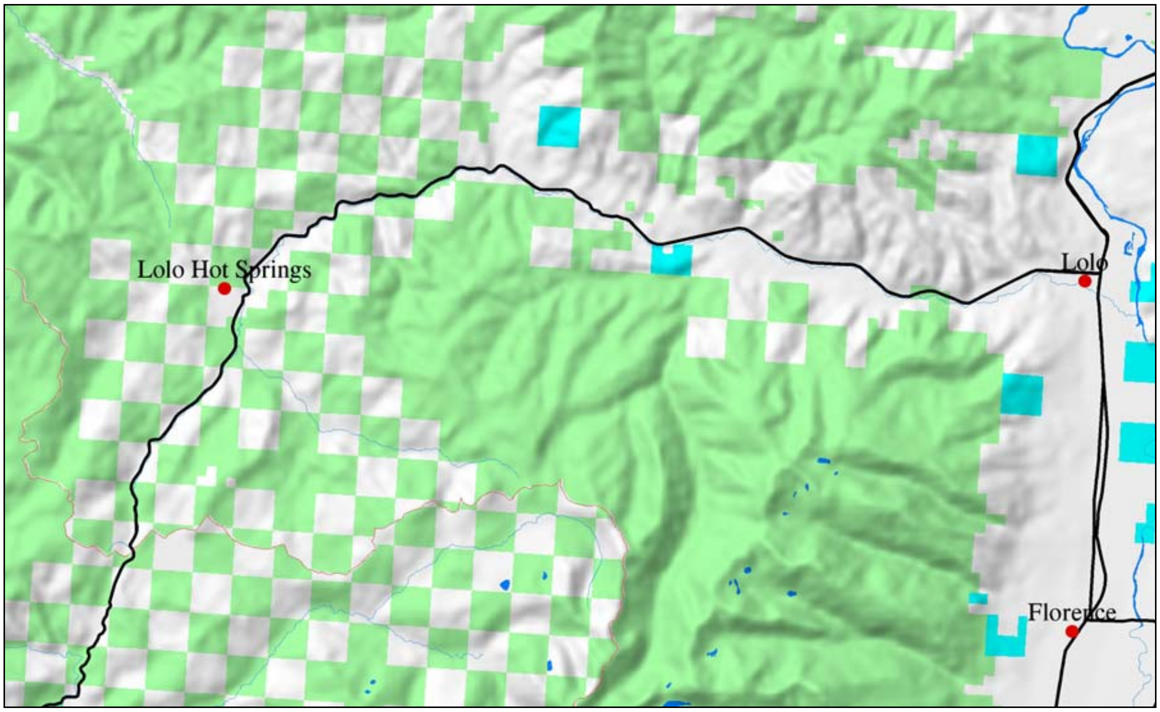


Figure 27. Land ownership along Highway 12 between Lolo, Montana and Lolo Pass on the Idaho border. Green is USFS, blue is state, white is private. Much of the checkerboard private land from east of Lolo Hot Springs to Idaho is owned by Plum Creek Timber Co.

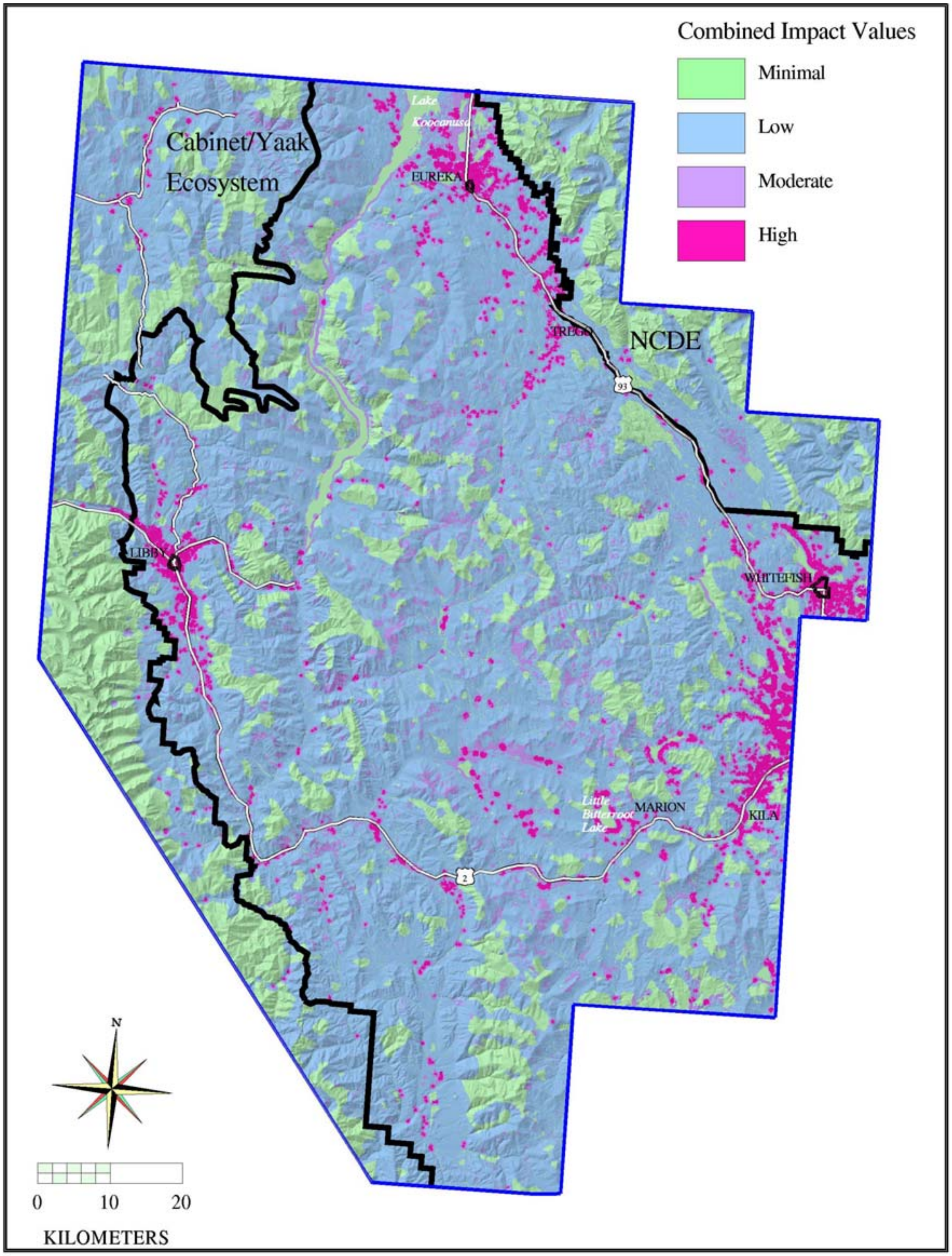


Figure 28. Linkage Zone Prediction Model output for the NCDE to Cabinet/Yaak ecosystems evaluation area.

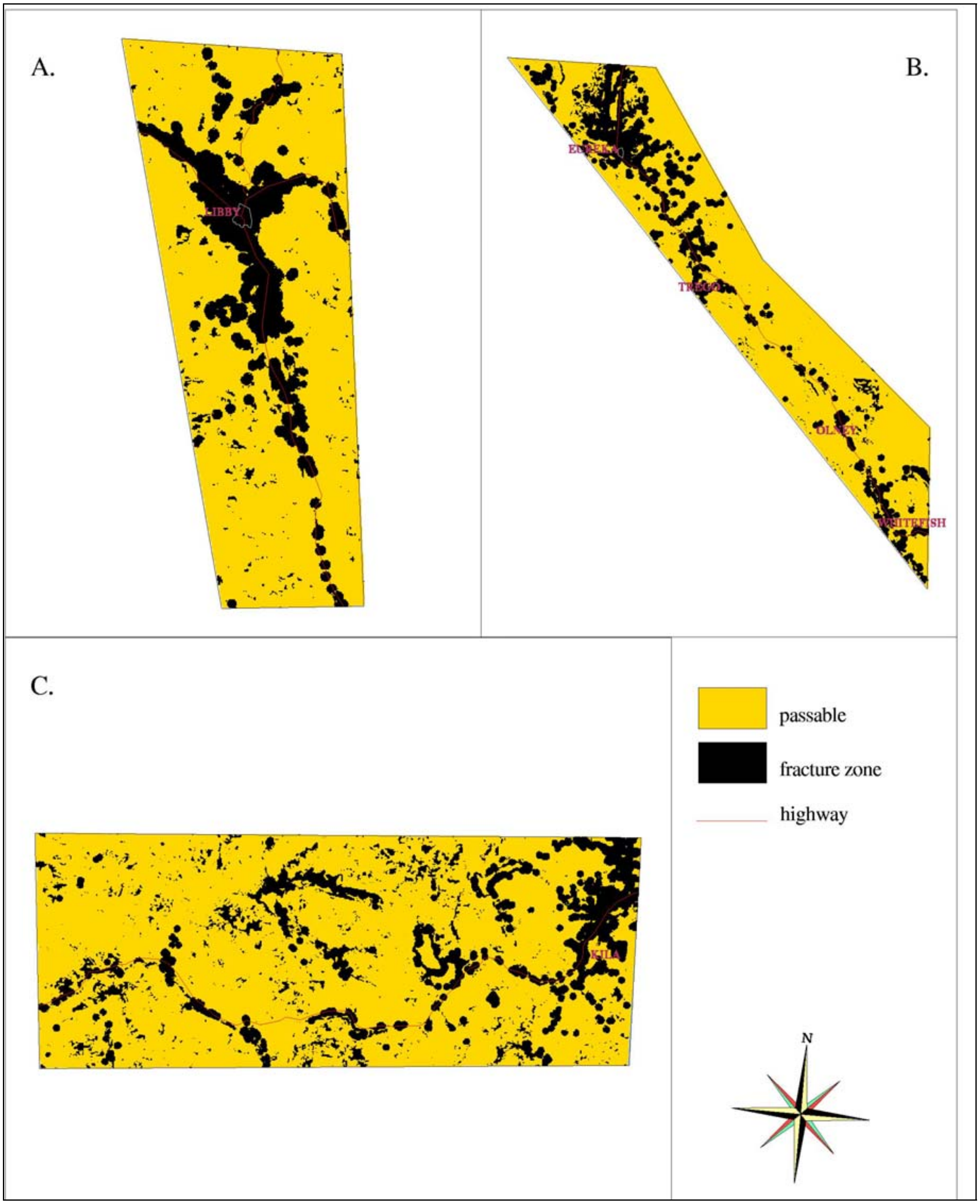


Figure 29. Linkage Zone Prediction Model output for mountain valleys in the NCDE to Cabinet/Yaak linkage zone evaluation area. Yellow is minimal impact. Black is moderate to high impact. A. Highway 2 - Sedlak Park to Libby, Montana. B. Hwy 93 - Whitefish to Eureka, Montana. C. Hwy 2 - Sedlak Park to Kila, Montana.

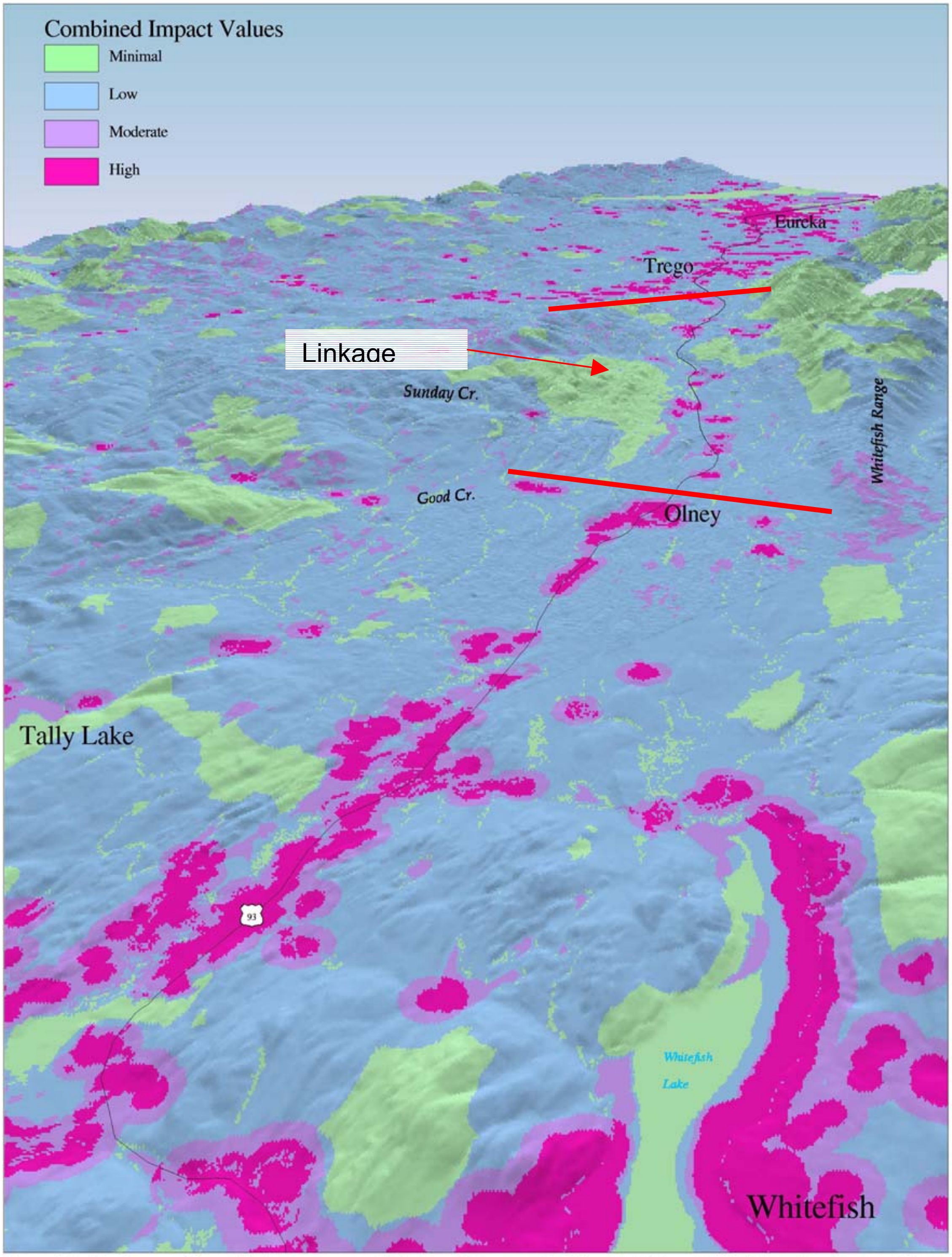


Figure 30. Landscape view Linkage Zone Prediction Model output looking north from Whitefish to Eureka.

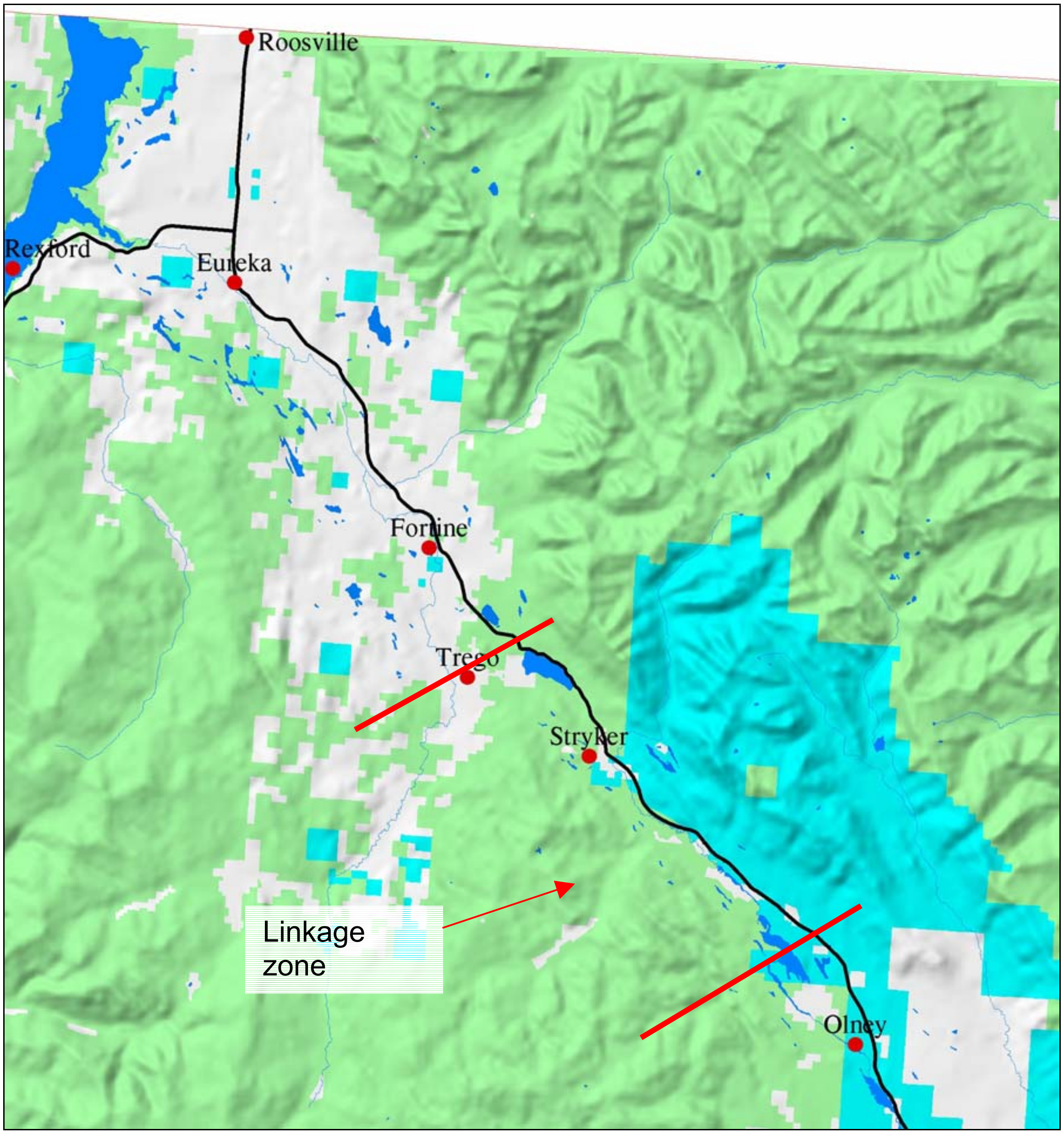


Figure 31. Land ownership along Highway 93 between Olney, Montana and Canada. Green is USFS, blue is state, white is private.

Cr. and Cayuse Cr. (Figures 23, 25). The third lies just south of Tarkio between Cyr Peak and Freezeout Gulch.

US Highway 12 presents less of an obstacle than I-90 because of the lower levels of human development along the highway, especially west of Lolo Hot Springs, and the fact that it is a lower volume two lane road rather than an interstate highway. Although rural development continues approximately 10 miles up US-12 west of the town of Lolo to Woodman Cr., it dissipates rapidly thereafter, and should not impede linkage (Figures 27, 28).

NCDE to Cabinet/Yaak

This was the largest linkage evaluation area, covering nearly 5,000 sq. mi. Within this area there appeared to be only 2 obstacles to wildlife movement between the NCDE and the Cabinet/Yaak. These were US Highway 93, and US Highway 2 (Figure 29).

US Highway 93 connected the community of Eureka, near the Canadian border, to Whitefish and Kalispell to the south. These 3 communities have experienced rapid growth and increasing development along the 52 miles of highway between them (Figure 30B). Habitat fragmentation was nearly complete between Whitefish and Tally Lakes to the town of Olney, although a small crossing area existed just south of Olney (Figure 31). The best opportunities for linkage were between Olney and Trego, allowing movement from the Whitefish Range in the east to the Good and Sunday Creek drainages to the west (Figures 31, 32). Little opportunity existed between Trego and Eureka.

US Highway 2 connects the cities of Kalispell and Libby, 89 miles to the west. Kalispell has been actively expanding to the west along the US 2 corridor and now is contiguous with the community of Kila (Figure 33). Corridor development continued from Kalispell and Kila in a dispersed fashion to the town of Marion near Little Bitterroot Lake, a popular recreation site (Figure 30C). West of Marion, linkage areas were scattered but allowed numerous crossing opportunities (Figure 33). Development again became more concentrated approaching the community of Libby (Figure 30A). Small, scattered crossing opportunities existed until just north of Poker Hill, approximately 12 miles south of Libby (Figure 34).

Yaak to Cabinets

US Highway 2 separates the Cabinet Mountains and the Yaak River drainage. The Cabinet Mountains are further bisected by Montana Highway 56 (Figures 35, 36). The community of Libby has grown westward along US 2 towards the community of Troy, 18 miles distant. Reasonably safe areas for crossing the US 2 corridor occur in a small section of highway midway between Troy and Libby at Burrel and Dad Creeks (Figures 37, 38). An alternative is to cross US 2 north of Troy, at the confluence of the Kootenai and Yaak Rivers (Figures 37, 39). They then may proceed south into the East and West Cabinet Mountains. However, to access the Cabinet Mountains Wilderness in the east or main Cabinet Range, they must cross Montana Highway 56 (Figures 40, 41).

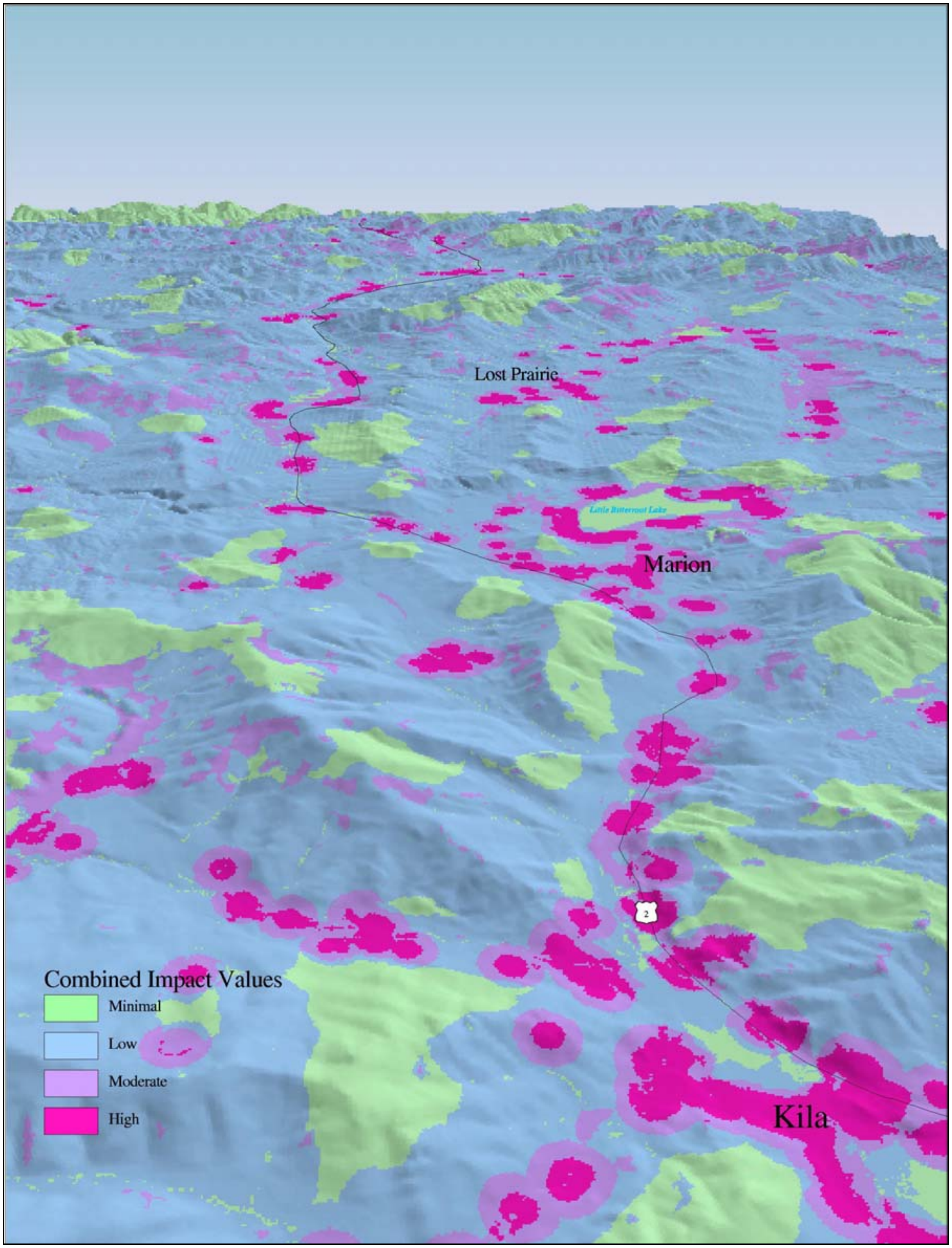


Figure 32. Landscape view of Linkage Zone Prediction Model output looking west from Kila to Sedlak Park, Montana along Highway 2.

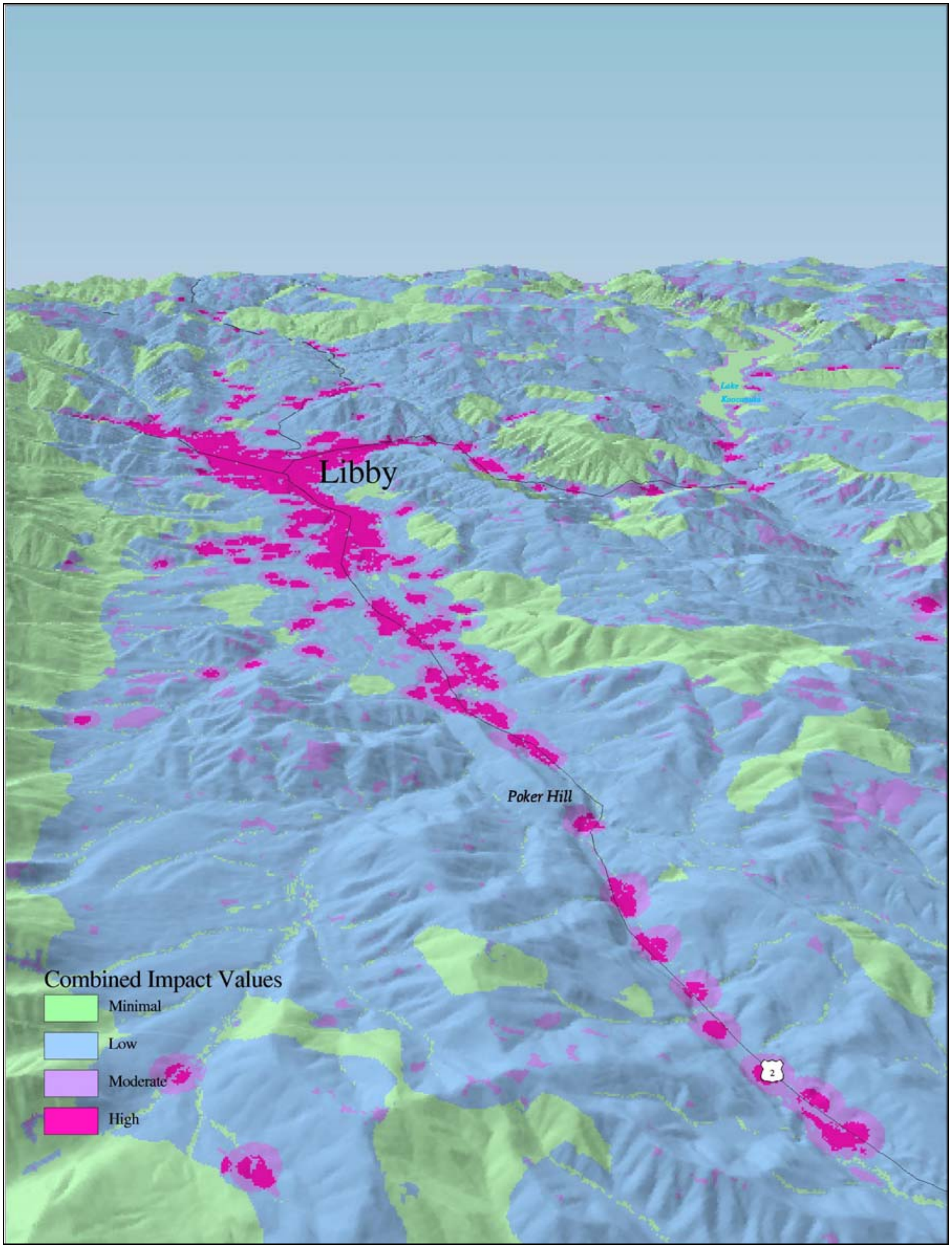


Figure 33. Landscape view of Linkage Zone Prediction Model output from Sedlak Park to Libby, Montana along Highway 2.

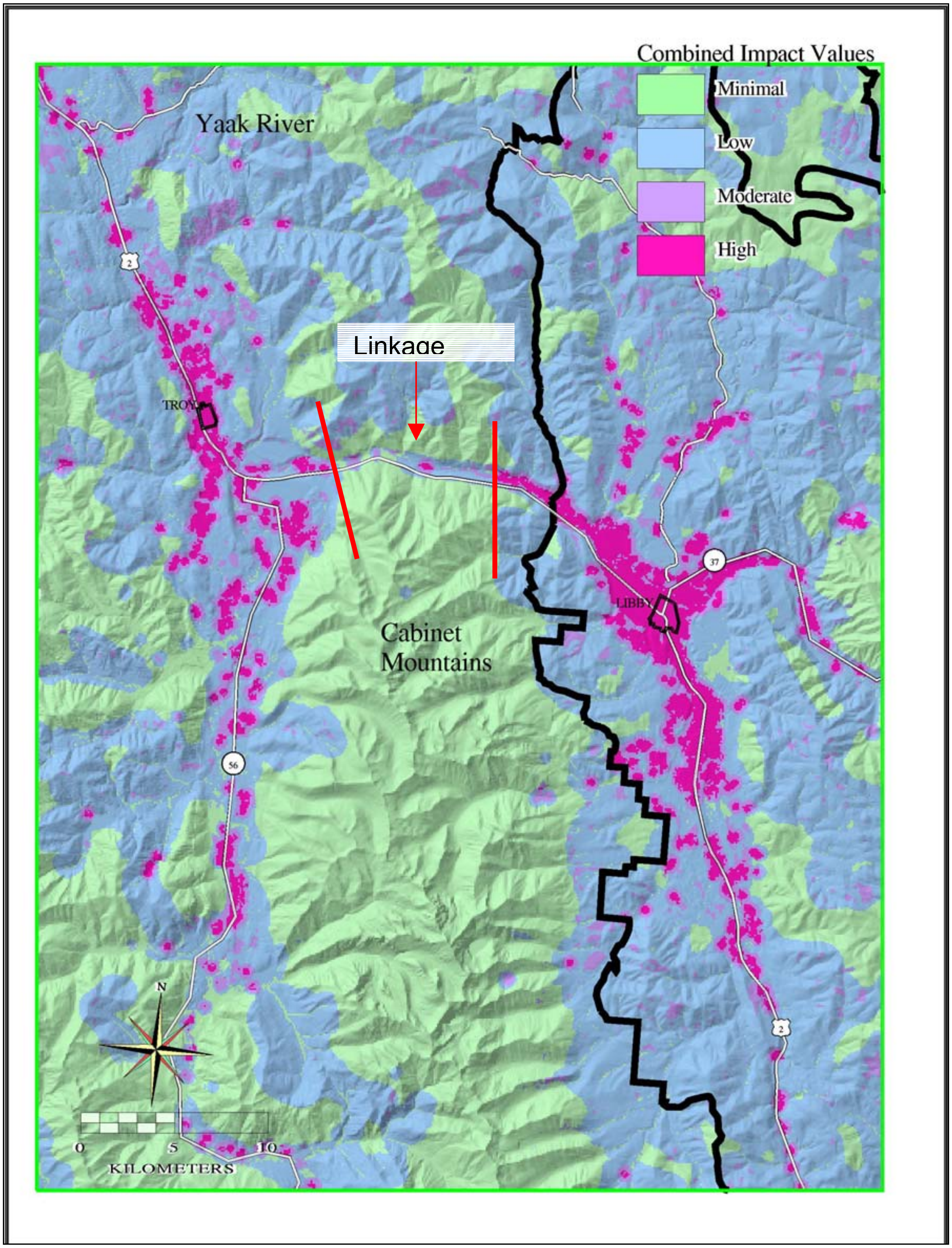


Figure 34. Linkage Zone Prediction Model output for the area along Highway 2 between the Yaak River area and the Cabinet Mountains in the Cabinet/Yaak ecosystem.

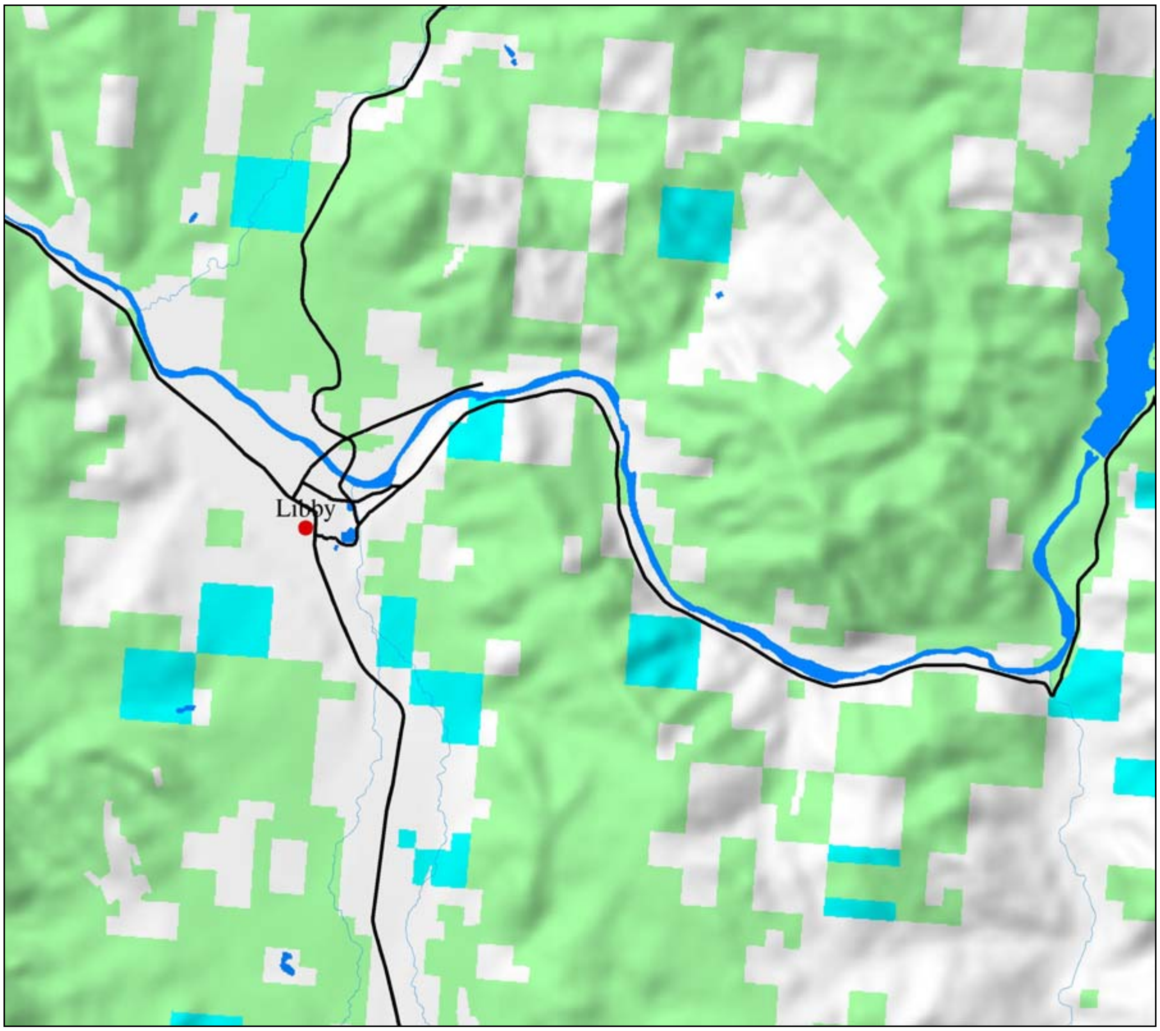


Figure 35. Land ownership along Highway 2 east of Libby, Montana. Green is USFS, blue is state, white is private.

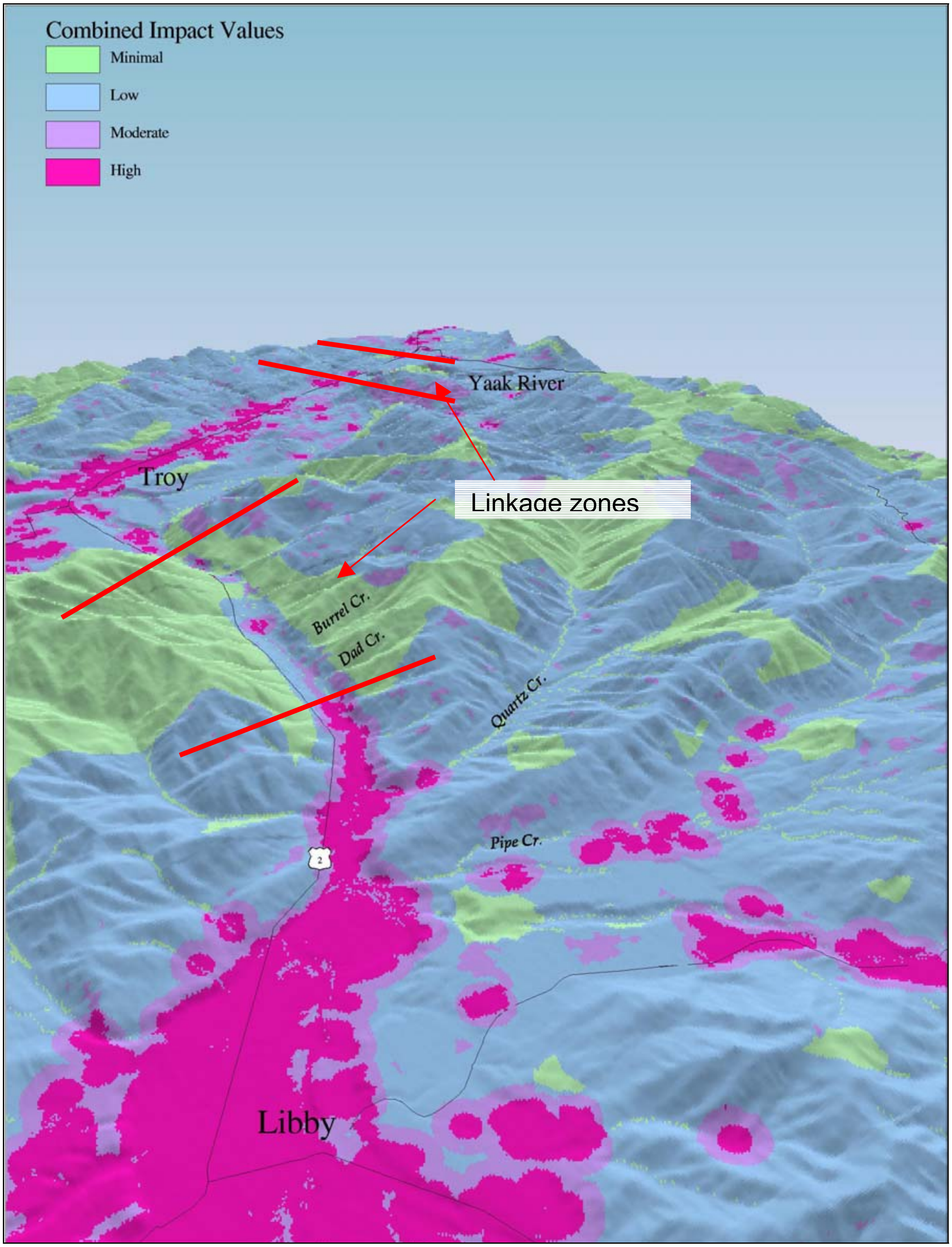


Figure 36. Landscape view of Linkage Zone Prediction Model output looking west from Libby along Highway 2.

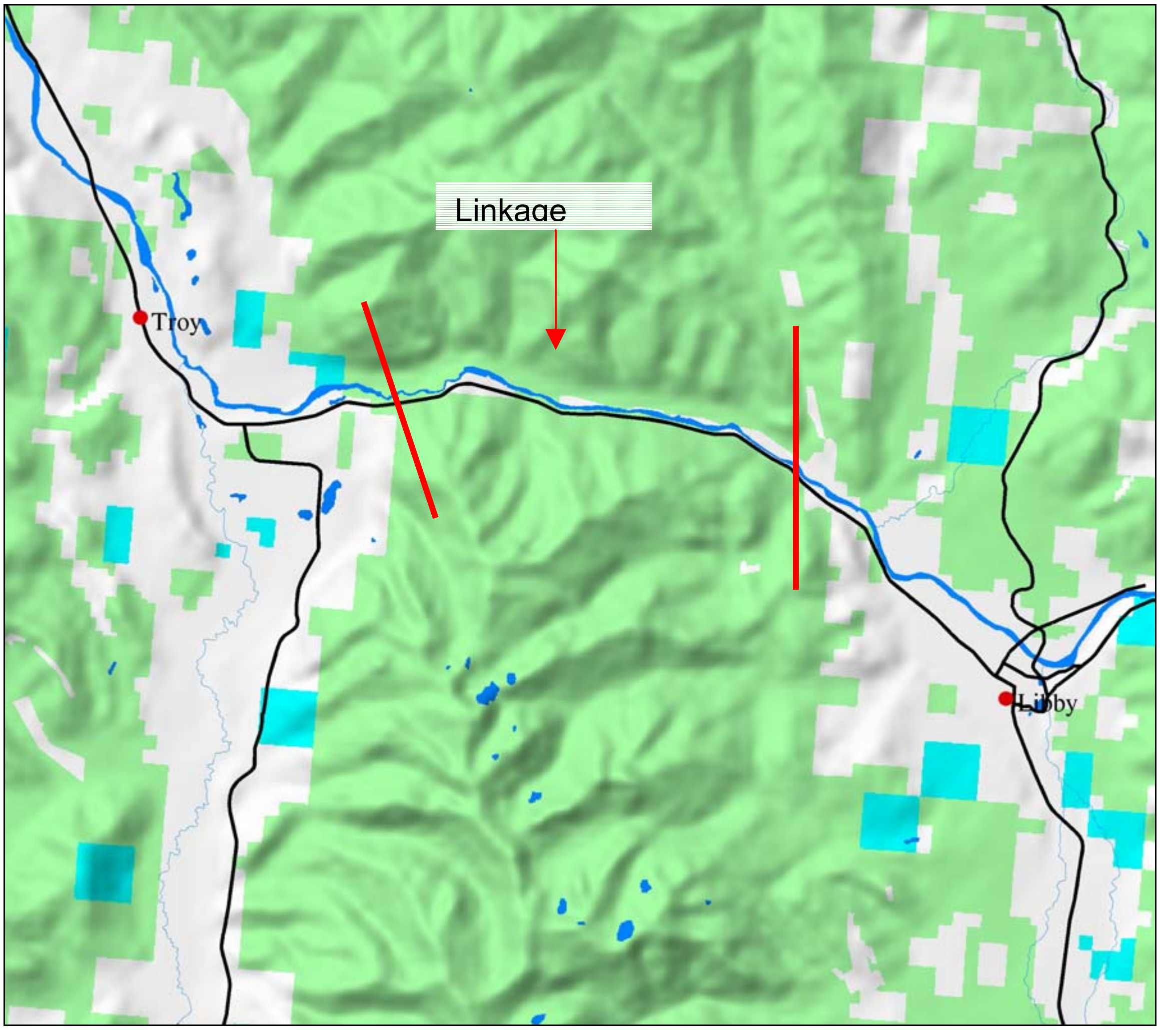


Figure 37. Land ownership along Highway 2 between Libby and Troy, Montana. Green is USFS, blue is state, white is private.

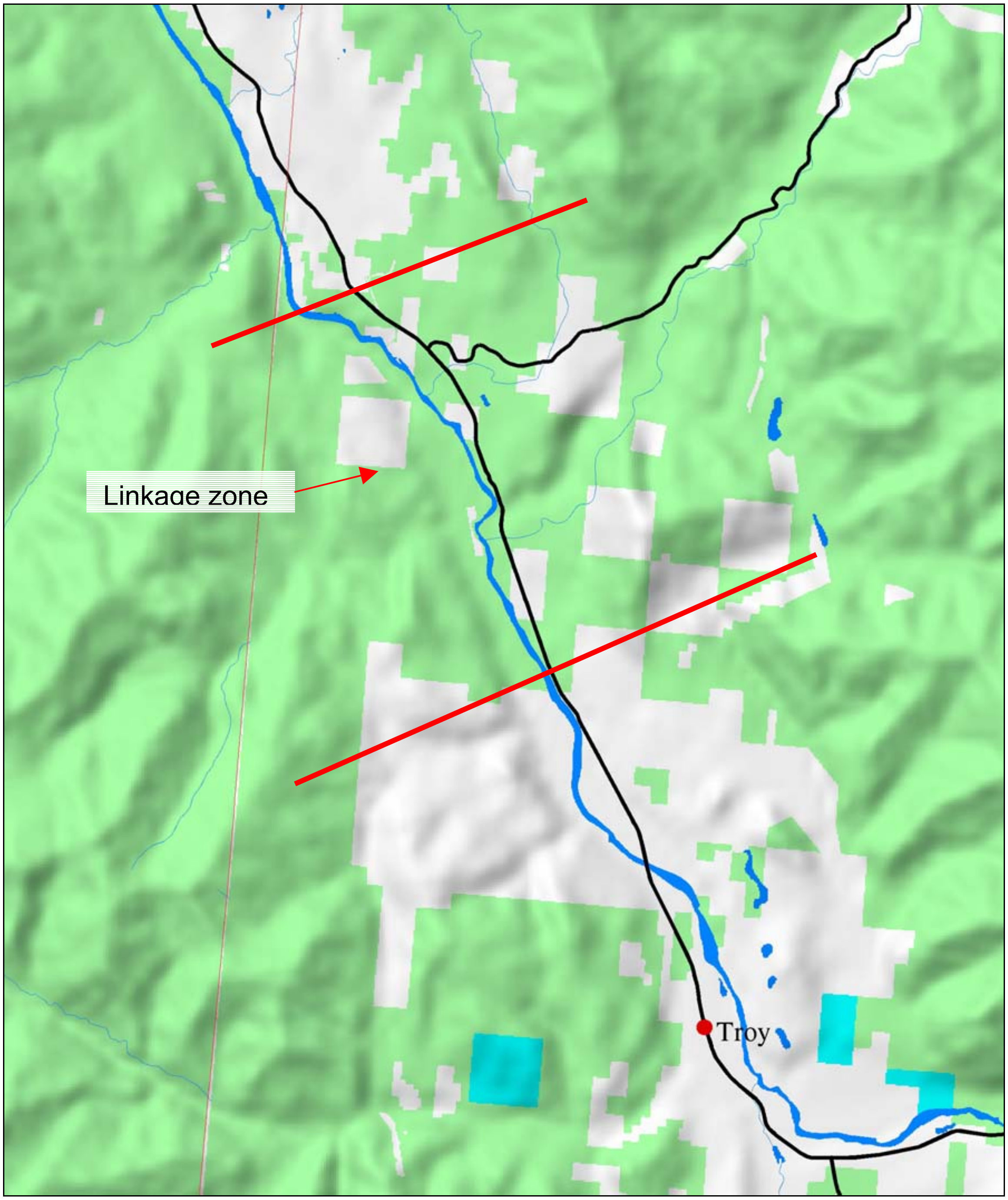


Figure 38. Land ownership along Highway 2 between Troy, Montana and Idaho. Green is USFS, blue is state, white is private.

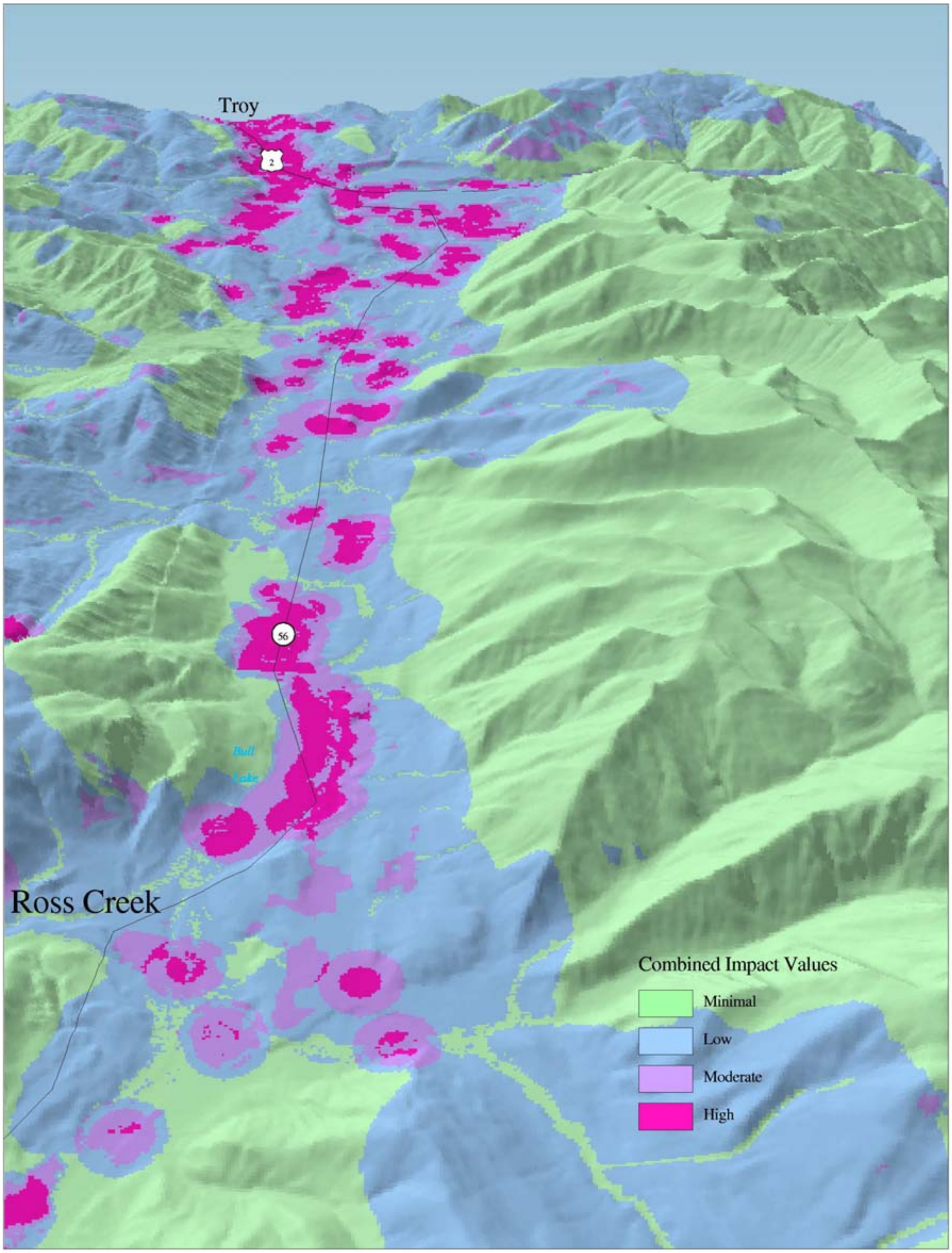


Figure 39. Landscape view of Linkage Zone Prediction Model output looking from Bull Lake to Troy, Montana.

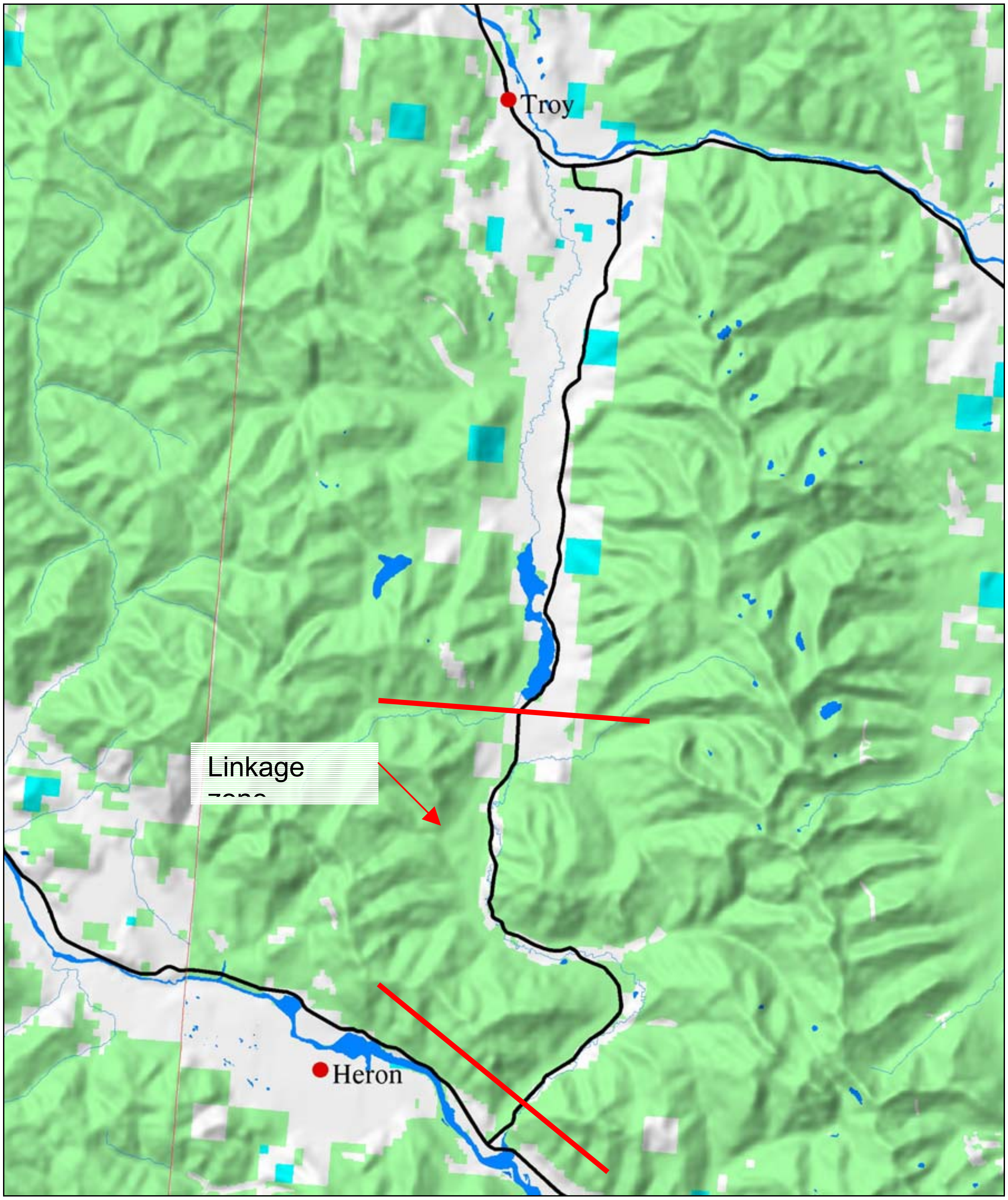


Figure 40. Land ownership along Highway 56 along the Bull River inside the Cabinet/Yaak ecosystem. Green is USFS, blue is state, white is private.

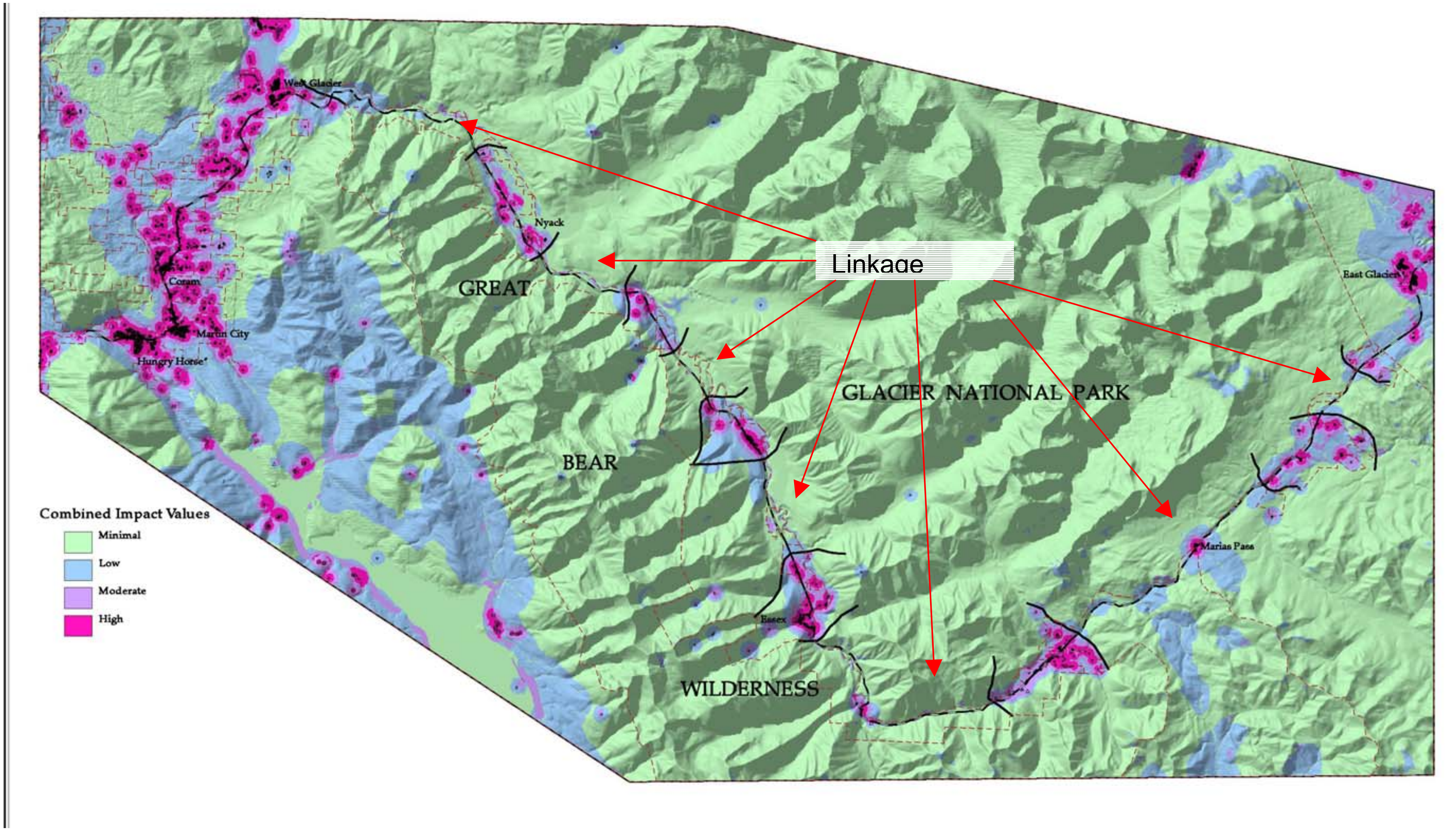


Figure 41. Linkage Zone Prediction Model output from East Glacier to West Glacier, Montana along Highway 2.

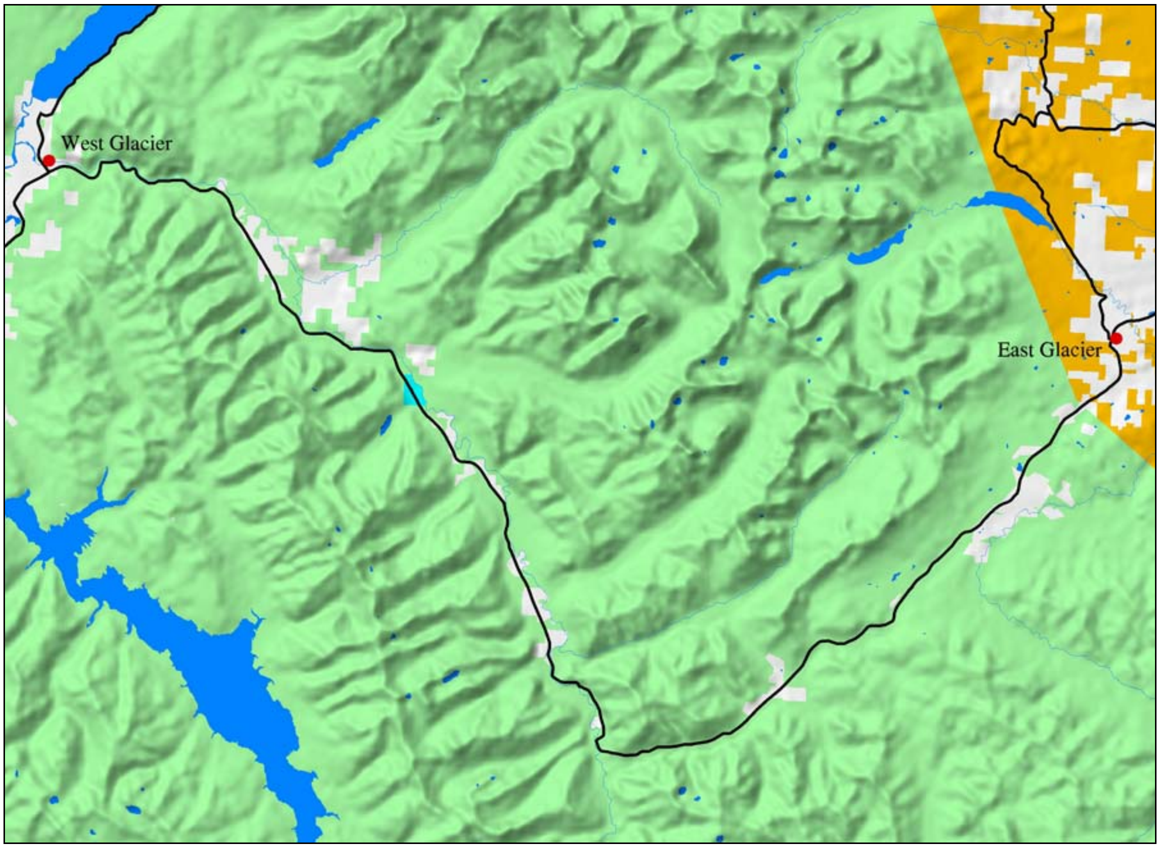


Figure 42. Land ownership along Highway 2 from East Glacier to West Glacier, Montana. Green is USFS, blue is state, white is private.

Across Highway 2 in the NCDE

Linkage across Highway 2 in the NCDE is critical to maintain historic wildlife movement patterns in NCDE. At present, several linkage areas exist in the section of Highway 2 between East Glacier and West Glacier, Montana (Figures 42, 43).

Highway 2 as a 4-lane highway

There have been discussions about making Highway 2 a 4-lane highway across Montana. If this were to happen, it would have a high probability of fracturing wildlife populations in the NCDE and the Cabinet/Yaak areas. If conversion of this 2-lane road to a 4-lane highway were to take place, information on how wildlife respond to and cross 4-lane highways would have to be used to try and develop mitigation designs. This highway could impact the future of several species including some species listed under the Endangered Species Act.

Discussion

This assessment does not present a bright outlook for potential connectivity for wildlife across the northern Rockies. Fragmentation is ongoing between most of the large blocks of land in the Northern Rockies. Development has continued at a record pace and it is likely that linkage areas we identified may become unavailable within the next decade. However, the following discussion of the LZP model may inject some cause for optimism.

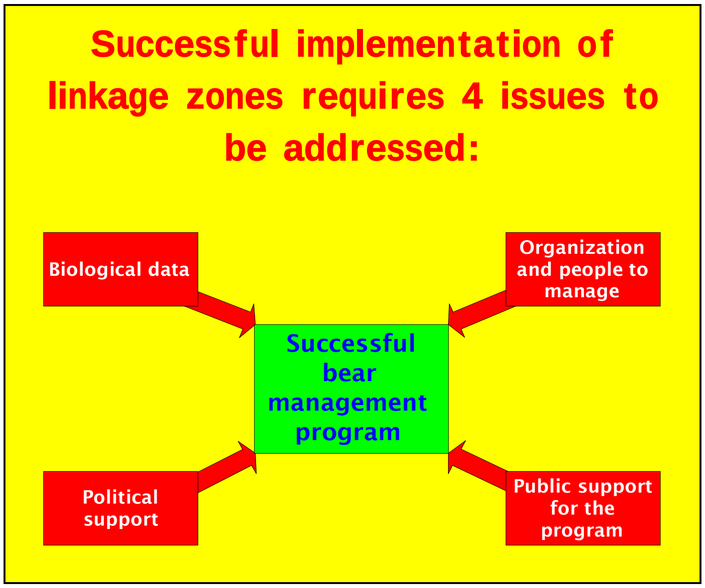
A model is an abstraction of reality that

The need to field check linkage zone sites

Linkage zones should be field checked to verify boundaries and to adjust for unknown developments or activities in these areas. We have attempted to digitize and score all human developments across literally thousands of square miles of habitats. Given the pace of development and errors or omissions in databases, it may be possible that changes need to be made in the specific boundaries of each zone. We feel confident that general locations of the linkage zones on the maps in this report do represent the best areas for crossing opportunities for wildlife but field checking is necessary, especially by people familiar with the area, as linkage zone implementation and management get underway.

simplifies natural processes into understandable components. The LZP model attempted to quantify those components most responsible for influencing wildlife movements, then use those components to identify places where animals are most likely to traverse human developments. The model operated with geographic data collected at landscape scales. Thus, it was insensitive to fine scale environmental patterns. Most large mammals, on the other hand, are well equipped to process information collected at fine scales. Model outputs reflected the quality of input data. Errors in digital maps of terrain, human developments, and roads were reflected in model results. Thus the LZP model may not accurately predict exactly where animals will choose to cross-fractured habitat. Further, human development is a continuous process. Digital maps of roads and developments, that were accurate at the time we obtained them, may not show more recent developments.

The LZP model should be considered a point of departure for more intensive and more accurate mapping of potential linkage zones. Although we felt confident that the model accurately portrays places where large mammals have the highest probability of successfully crossing fractured habitat , implementation of conservation strategies will require that the model be validated in the field. The LZP model also contains many assumptions about the relative risk of each of its components to wildlife. Some of these assumptions are poorly substantiated due to the lack of pertinent research, for example the strength of reaction to human developments in relation to cover conditions.



In these cases, we used our best judgment to estimate risk and aversion.

As the number of linkage zones between the large blocks of public lands decreases, the likelihood of movement opportunities for wildlife diminishes. The spatial extent of remaining linkage areas is becoming very small relative to the movement needs of large mammals. Wildlife will then be more likely to attempt crossings in less safe areas, increasing their risk of mortality. There is no research concerning minimum required size of linkage zones or at what level linkage areas become ineffective for wildlife connectivity. Such information can only be obtained through long term and intensive wildlife monitoring. Recent advancements in GPS technology on collars worn by large mammals may allow researchers to answer questions of this nature in the near future. However, we strongly believe that the available information is sufficient to move ahead and begin the process of linkage zone implementation.

The LZP model, as applied here, does not consider habitat quality as an important factor governing wildlife movements. It does use presence of riparian areas, modeled from terrain data, as a factor, but this treatment is superficial at best. The reason for this is that classified and validated maps of habitat quality for various species are generally non-existent. Creating them from field research is time consuming and expensive. However recent research into habitat selectivity for some species using satellite imagery and radio telemetry data have found strong associations between telemetry locations and vegetation reflectance patterns (Manley et al. 1992, Mace et al. 1999). It may be possible to map wildlife habitat quality across broad landscapes using satellite imagery. Such information

Key issues for successful management of linkage zones

- <u>Public involvement</u> in the development and application of linkage zone management.
- <u>Public support</u> and understanding of the goals of the linkage zone effort.
- <u>Agency land management planning</u> in linkage zones to maintain characteristics of these areas necessary for wildlife.
- <u>State DOT planning on highway improvement</u> and modification, if necessary, to facilitate wildlife movement across highways in linkage zones.

could then be incorporated into a more habitat-specific linkage prediction model.

A cumulative effects modeling (CEM) process is underway in some area that uses this type of approach to estimate the effects of human activities on habitat (Waller 1999). This process could be evaluated as an addition to the LZP.

Options for Implementation and Management of Linkage Zones

The plan of action to address the Linkage zone issue:

1. Identify where movement opportunities still exist between ecosystems with completion of the linkage zone report.
2. Prioritize the areas where linkage zone emphasis is most important now.
3. Develop management strategies for public lands and highways in identified linkage zones to maintain the opportunities for linkage for wildlife in the Northern Rocky Mountains.
4. Develop a cooperative plan to work with local groups and county governments similar to how it was done in the Swan Valley, Montana to engage local people in the issue of linkage for wildlife populations in their valley areas.

Linkage zones cross multiple land ownerships including public lands primarily managed by the US Forest Service, state lands, and private lands. As such, successful implementation of linkage zones will require simultaneous efforts addressed at public lands, private lands, and transportation networks such as highways within each linkage zone. Efforts must be simultaneous because a lack of consideration for linkage zone needs on one land ownership area or on highways will negate efforts undertaken on adjacent ownerships or highways.

Implementation of linkage zone management requires different approaches for each land ownership. Implementing linkage zone management will require some new considerations in the way public lands are managed. It

Ideas on how to prioritize the linkage areas for implementation action

Criteria for prioritization include:
–Areas between the largest size blocks of public lands
–Short links should be emphasized first
– Areas where there is a high probability of future linkage use with high chance of success
–Multiple species linkage benefits when possible
–High percentage of public land in the linkage area
–Any area having current use by one or more forest carnivores that may be threatened is higher priority than areas currently unused

will require consideration of highway improvement designs to facilitate wildlife crossing of highways at key areas within linkage zones. It will also require cooperative efforts with private landowners that can only be accomplished at the local level. This requires time and effort, and careful listening to landowners who have concerns about this issue. Their concerns must be addressed with good information and with sensitivity.

Suggested priority linkage areas to be addressed initially

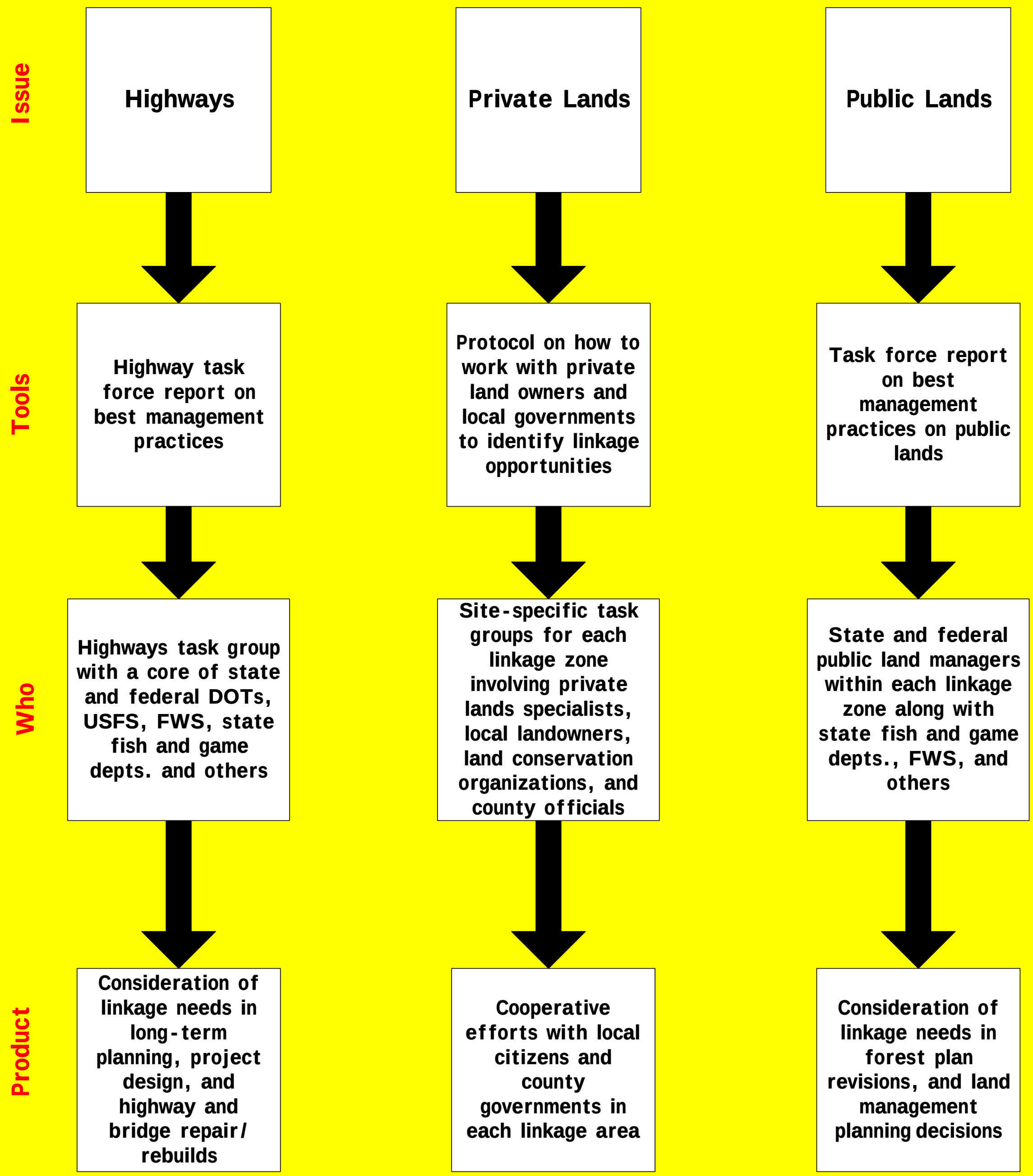
- Identified linkage zones along Highway 200 in Montana between Thompson Falls and the Idaho line
- Identified linkage zones along I-90 in Montana between St. Regis and Lookout Pass
- Identified linkage zones on Highway 95 in Idaho between Colburn and Bonners Ferry

Linkage zone management is a good example of a program that must have all four factors in place for a successful public policy – biological data, an organizational structure and people to implement the action, political support, and public support (adapted from Kellert and Clark 1991). Efforts must continue on each of these four factors if linkage zones are to become established and functional.

We suggest that the best way to implement linkage zone management is to develop task forces of specialists to address each of the key issue areas for linkage zones – public land management, private lands, and coordination with state and federal highway issues. These task forces will produce a set of recommendations on best management practices for linkage implementation and for cooperation with highway departments. A protocol to work with private landowners will also be developed.

Private landowners who have already worked cooperatively to implement linkage zones in local communities will write this protocol. This private lands protocol will describe the best ways to work with local landowners in order to obtain understanding and ownership of the ideas necessary for linkage zone management. These task force reports can then be the template to implement management opportunities on public lands in the approach zones to each linkage zone, to implement planning and outreach with private landowners in each area, and to incorporate linkage zone crossing opportunities into highway planning in each linkage zone.

The simultaneous three-pronged approach to linkage zone implementation that will address all the necessary issues:



Possible crossing management ideas for *highways* in linkage zones:

- Develop baseline information on the species in each linkage area and the most likely areas to be used for crossing based on monitoring information
- At sites where crossings are needed, maintain vegetative cover as close to highway as possible
- Minimize highway width
- Elevate highways over natural crossing routes such as streams and provide streamside space for wildlife travel under the highway
- Minimize the use of barriers such as concrete medians that can block crossing by wildlife and increase mortality risk for those animals that do venture onto the highway
- Pursue opportunities to provide naturally vegetated crossing structures over highways in association with topographic features where hill-slope cuts would normally be used

What is necessary to maintain linkage opportunities on *public lands* in linkage zones?

On public lands in linkage zones:

- Consider maintaining habitat security by motorized access control and maintenance of visual cover, especially along riparian zones, as management guidance
- Maintain secure habitat up to private land boundaries and up to highways
- Minimize livestock allotment impacts, especially in seasonally important habitats when carnivores may be present
- Preclude site developments such as campgrounds, rest areas, picnic areas, and other human site developments inside linkage zones that can reduce security for wildlife and that can tend to make wildlife avoid these areas

What is necessary to maintain linkage opportunities on *private lands* in linkage zones?

- **On private lands in linkage zones–**
- Work gradually one-on-one with local community leaders to explain the issue and how they can participate in ways that will enhance the value of linkage zones to wildlife while minimizing any problems for landowners in these areas.
- Involve local people in each area in the process and the implementation of efforts to maintain wildlife movement opportunities.
- Stress issues of rural nature, local interest, and maintenance of property values that are associated with maintenance of open space that linkage zones require.
- Work with community groups to build understanding and support and to act as focus groups on this issue at the community level.
- Work with county commissioners as local support is established.

Future considerations for linkage zones

- It is possible to maintain many of the remaining wildlife linkage opportunities if we organize to do so.
- Linkage opportunities are threatened by ongoing development.
- The time to establish linkage opportunities is rapidly closing as development continues – perhaps only 10 years remain to complete this task.
- Once linkage is gone, maintaining healthy wildlife populations will be more difficult.

It is easier to maintain wildlife linkage where it exists than to recreate it once it is lost

Literature Cited

Almack, J. A. 1986. Grizzly bear habitat use, food habits, and movements in the Selkirk Mountains, northern Idaho. Pgs. 150-157 *in:* G. P. Contreras and K. E. Evans, editors. Proceedings – Grizzly bear habitat symposium. General Technical Report INT-207, U.S. Forest Service.

Apps, C. 1997. Identification of grizzly bear linkage zones along the Highway 3 corridor of Southeast British Columbia and Southwest Alberta. Aspen Wildlife Research, Calgary, Alberta.

Archibald, N.J., R. Ellis, and A.N. Hamilton. 1987. Responses of grizzly bears to logging truck traffic in the Kimsquit River Valley, British Columbia. International Conference on Bear Research and Management 7:251-257.

Aune, K., T. Stivers, and M. Madel. 1984. Rocky Mountain Front grizzly bear monitoring and investigation. Montana Department Fish, Wildlife and Parks, Helena, Montana.

Aune, K., and W. F. Kasworm. 1989. East Front grizzly bear study; final report. Montana Department Fish, Wildlife and Parks. Helena, Montana.

Blanchard, B. M. 1978. Grizzly bear distribution in relation to habitat areas and recreational use: Cabin Creek-Hilgard Mountains. M.S. Thesis. Montana State University, Bozeman, Montana.

Boyce, M.S., E. Kirsch, and C. Servheen. 2001. Bet-hedging applications for conservation. BioScience (in press)

Craighead, J. J., J. S. Sumner, and G. B. Scaggs. 1982. A definitive system for analysis of grizzly bear habitat and other wilderness resources. Wildlife-Wildlands Institute Monograph No. 1. University of Montana Foundation, Missoula, Montana.

Forman, R. T. T. 1995. Land mosaics: the ecology of landscapes and regions. Cambridge University Press, Cambridge, UK.

Garland, T., and V. G. Bradley. 1984. Effects of a highway on Mojave Desert rodent populations. American Midland Naturalist 111(1):47-56.

Gilpin, M.E., and M.E. Soule. 1986 Minimum viable populations: Processes of species extinction. Pages 19-34 *In:* M.E. Soule, editor. Conservation biology: The science of scarcity and diversity. Sinauer Associates, Sunderland, Massachusetts, USA.

Hanski, I., and M. Gilpin. 1991. Metapopulation dynamics: Brief history and conceptual domain. Biological Journal of the Linnean Society 42:3-16.

Hanski, I. 1999. Metapopulation ecology. Oxford University Press, Oxford, U.K.

Harrison, S. 1994. Metapopulations and conservation. Pages 111-128 in P. J. Edwards, R. M. May and N. R. Webb, eds. Large-scale ecology and conservation biology. Blackwell Scientific Press, Oxford, U.K.

Interagency Grizzly Bear Committee (IGBC). 1994. Grizzly bear motorized access management task force report. U.S.D.A. Forest Service, Missoula, Montana.

Kasworm, W. F. 1985. Cabinet Mountains grizzly bear study. 1984 Annual Progress Report. U.S. Fish and Wildlife Service, Helena, Montana.

Kasworm, W.F., and T.L. Manley. 1990. Road and trail influences on grizzly bears and black bears in northwest Montana. International Conference on Bear Research and Management 8:79-84.

Kellert, S. and T. Clark. 1991. The theory and application of a wildlife policy framework. Pp. 17-35 *in* W.R. Mangun and S.S. Nagel, eds. Public policy and wildlife conservation. Greenwood, New York.

Lande, R. and G.F. Barrowclough. Effective population size, genetic variation, and their use in population management. Pp. 87-123. *in* M. Soule (ed.) Viable Populations for Conservation. Cambridge University Press. New York, New York.

Levins, R. 1970. Extinction. Pp. 77-107 *in* M. Gustenhaver (ed.) Some Mathematical Questions in Biology, Vol. II. American Mathematical Society. Providence, Rhode Island.

Ma, Z. 1994. Visualization/Mapping. Unpublished software. University of Montana, Missoula.

Mace, R. D., and C. Jonkel. 1979. Seasonal food habits of the grizzly bear in Northwestern Montana. Pgs 28-46 *in*: C. Jonkel, editor. Annual report No. 4, Border grizzly bear project. University of Montana, Missoula.

Mace, R. D., and C. Jonkel. 1980. Food habits of the grizzly bear in Montana. Pgs 49-69 *in:* C. Jonkel, editor. Annual Report No. 5, Border grizzly bear project. University of Montana, Missoula

Mace, R. D, and T. L. Manley. 1993. South Fork Grizzly Study; Progress Report. Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

Mace, R. D, and J.S. Waller. 1998. Demography and population trend of grizzly bears in the Swan Mountains, Montana. Conservation Biology 12(5):1005-1016.

Mace, R. D, J.S. Waller, T.L. Manley, L.J. Lyon, and H. Zuuring. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33:1395-1404.

Mace, R. D J.S. Waller, T.L. Manley, K. Ake, and W.T. Wittinger. 1999. Landscape evaluation of grizzly bear habitat in northwestern Montana. Conservation Biology 13(2):367-377.

MacArthur, R.H., and E.O. Wilson. 1967. The theory of island biogeograhy. Princeton University Press, Princeton, N.J.

Manley, T. L., K. Ake, and R. D. Mace. 1992. Mapping grizzly bear habitat using Landsat TM satellite imagery. Pp. 231-240 *in:* Remote Sensing and Natural Resource Management. Proceedings of the 4th Forest Service Remote Sensing Applications Conference.

Mattson, D.J., R.H. Knight, and B.M. Blanchard. 1987. The effects of developments and primary roads on grizzly bear habitat use in Yellowstone National Park, Wyoming. International Conference on Bear Research and Management 7:259-273.

McLellan, B. N., and R. D. Mace. 1985. Behavior of grizzly bears in response to roads, seismic activity, and people. Preliminary Report; Canadian Border Grizzly Project, Cranbrook, B.C.

McLellan, B.N., and D.M. Shackleton. 1988. Grizzly bears and resource-extraction industries: effects of roads on behaviour, habitat use and demography. Journal of Applied Ecology 25:451-460.

McLellan, B.N. and D.M. Shackleton. 1989. Immediate reactions of grizzly bears to human activities. Wildlife Society Bulletin 17:269-274.

McLellan, B.N. 1990. Relationships between human industrial activity and grizzly bears. International Conference on Bear Research and Management 8:57-64.

McLellan, B.N., and V. Banci. 1999. Status and management of the brown bear in Canada. Pgs. 46-50 *In:* Servheen, C., S. Herrero, and B. Peyton, compilers. Bears. Status survey and conservation action plan. IUCN/SSC Bear and Polar Bear Specialist Groups. IUCN, Gland, Switzerland and Cambridge, UK.

Mealey, S. P., C. Jonkel, and R. Demarchi. 1977. Habitat criteria for grizzly bear management. Proceedings of the International Congress of Game Biologists 13:276-289.

Mietz, S.N. 1994. Linkage zone identification and evaluation of management options for grizzly bears in the Evaro Hill area. M.S. Thesis. University of Montana, Missoula. 91 pp.

Mills, L.S., and P.E. Smouse. 1994. Demographic consequences of inbreeding in remnant populations. American Naturalist 144(3): 412-431.

Sandstrom, P.L. 1996. Identification of potential linkage zones for grizzly bears in the Swan-Clearwater Valley using GIS. M.S. Thesis. University of Montana. 72 pp.

Schallenberger, A., and C. Jonkel. 1980. Rocky Mountain east front grizzly studies, 1979. Border Grizzly Project Special Report No. 39. University of Montana, Missoula, Montana.

Servheen, C. 1983. Grizzly bear food habits, movements, and habitat selection in the Mission Mountains, Montana. Journal of Wildlife Management 47(4): 1026-1035.

Servheen, C. 1981. Grizzly bear ecology and management in the Mission Mountains, Montana. Ph.D. Dissertation, University of Montana, Missoula. 138 pp.

Servheen, C. 1990. The status and conservation of the bears of the world. Proceedings of the 8th International Conference on Bear Research and Management, Monograph Series No. 2. 32 pp.

Servheen, C., and P. Sandstrom. 1993. Ecosystem management and linkage zones for grizzly bears and other large carnivores in the northern Rocky Mountains in Montana and Idaho. Endangered Species Technical Bulletin 18(3).

Servheen, C., J. Waller, and W. Kasworm. 1998. Fragmentation effects of high-speed highways on grizzly bear populations shared between the United States and Canada. Pp. 97-103 *in* G. Evink, P. Garrett, D. Zeigler, and J. Berry, eds. Proceedings of the International Conf. on Wildl. Ecol. And Transportation. FL-ER-69-98. Florida Dept. Transportation, Tallahassee, Florida. 263 pp.

Servheen, C. 1999. Status and management of the grizzly bear in the lower 48 United States. Pp. 50-54 *in* C. Servheen, S. Herrero, and B. Peyton, eds. Bears: Status Survey and Conservation Action Plan. IUCN/SSC Bear and Polar Bear Specialist Groups, IUCN, Gland, Switzerland and Cambridge, U.K. 309 pp.

Singleton, P.H., W.L Gaines, and J.F. Lehmkuhl. 2002. Landscape permeability for large carnivores in Washington: A GIS weighted-distance and least-cost corridor assessment. Research Paper PNW-RP-549, USDA Forest Service, Pacific Northwest Research Station, Portland OR.

Soule, M.E. 1983. What do we really know about extinction? *in:* C. M. Schonewald-Cox et al., editors. Genetics and Conservation. Benjamin Cummings, Menlo Park, California.

Soulé, M.E., editor. 1987. Viable populations for conservation. Cambridge University Press, New York.

USFS. 1992. Flathead National Forest hiding cover definition. Unpublished. Kalispell, Montana.

USFS. 1994. Cumulative effects modeling on the west side of the Northern Continental Divide Ecosystem. Unpublished notes. Flathead National Forest, Kalispell, Montana.

USFWS. 1993. Grizzly bear recovery plan. USFWS. Missoula, Montana. 181 pp.

USGS. 1987a. Digital elevation models: Data users guide. Reston, Virginia.

USGS. 1987b. Digital line graphs 1:24000: Data users guide. Reston, Virginia.

Waller, J. S. 1999. Using resource selection functions to model cumulative effects in the Northern Continental Divide Ecosystem. Report to the NCDE Managers Subcommittee of the IGBC. US Fish & Wildlife Service, Missoula, Montana.